THE ENGINEER

APRIL 29, 1960 | 28 ESSEX STREET, STRAND, LONDON, W.C.2 | TWO SHILLINGS

New and impressive from Ransomes & Rapier Ltd. . . . the RapieR 1520 loads up to 15 tons.

An exciting achievement. Britain's newest crane. Loads up to 15 tons. Booms up to 80 ft. Highly manoeuvrable even in confined cluttered spaces. Good all-round vision. Naturally-positioned controls. And it's really good-looking. Please write for full technical details.

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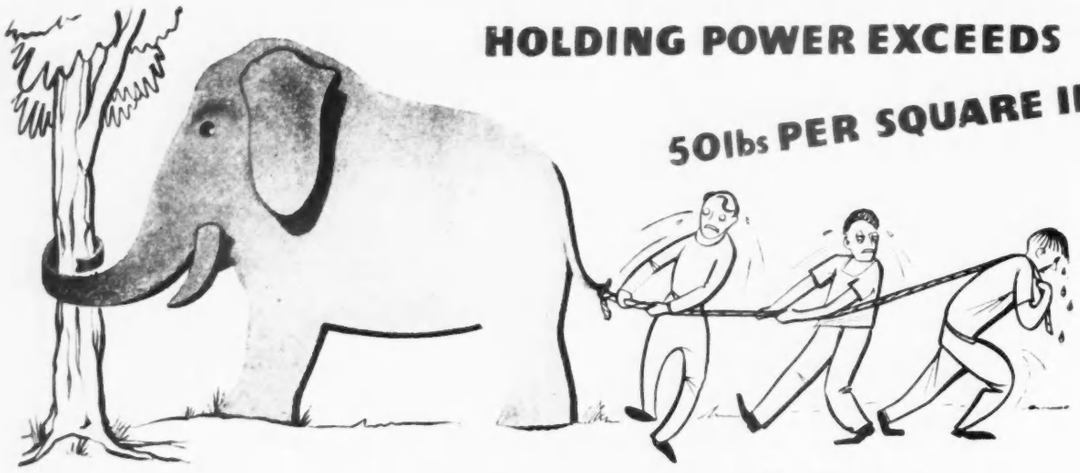

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More than 1,000 factories have done away with bolts, grouting, damaged floors; made layout changes a matter of hours; practically eliminated machine vibration. How? By adopting the Croid-Cooper method of machine installation where machines are stuck down on a felt base with a holding power of 50 lbs. to the square inch. Send for details to-day.

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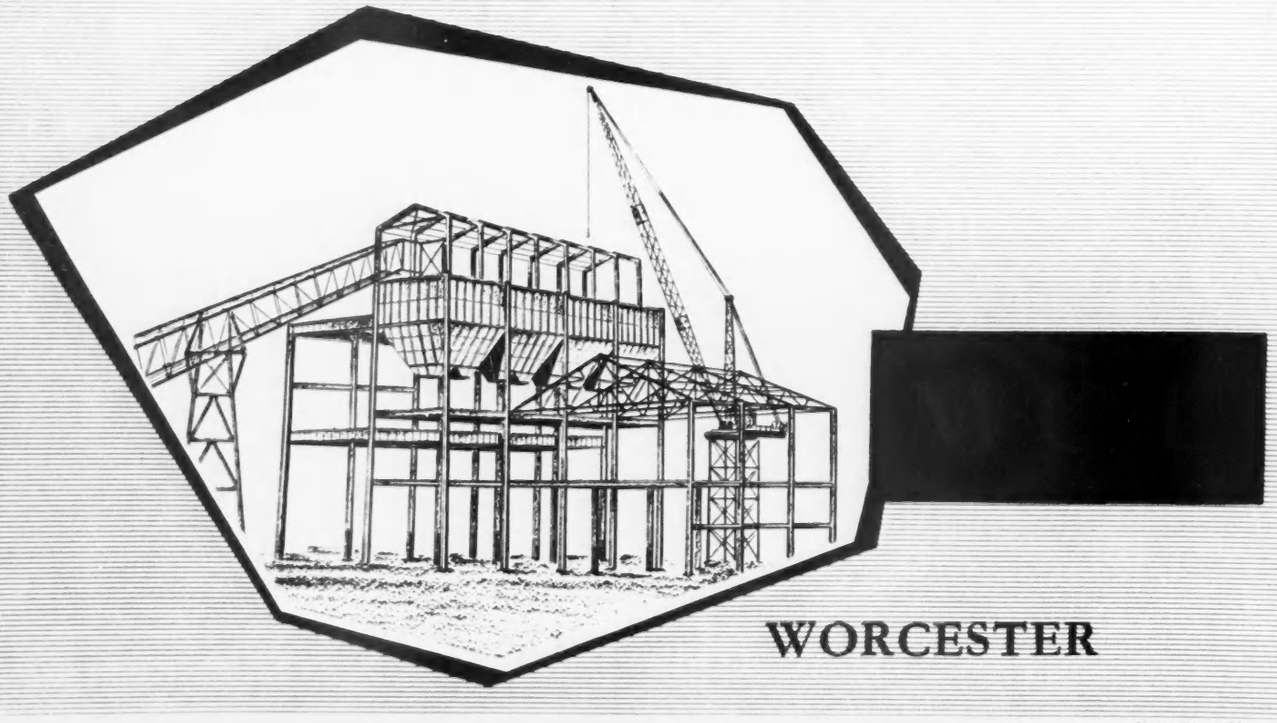

WORCESTER

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THE ENGINEER

Established 1856

No. 5440 **APRIL 29, 1960** VOL. 209

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'THE ENGINEER' BUYERS GUIDE Published annually. One FREE copy is sent to all direct postal subscribers on publication and delivered by newsagents to all regular readers. Additional copies are obtainable at 7s. 6d. each. Postage 1s. 9d. extra.

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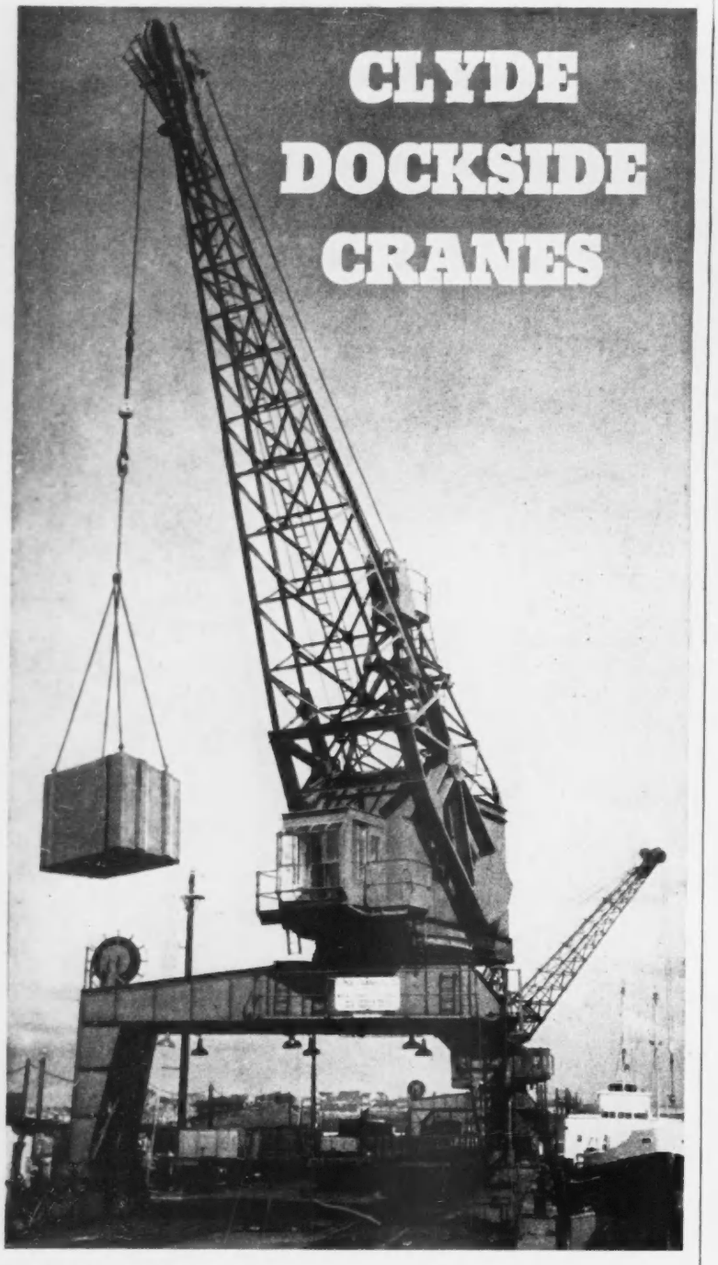

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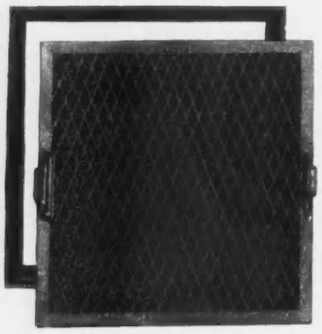
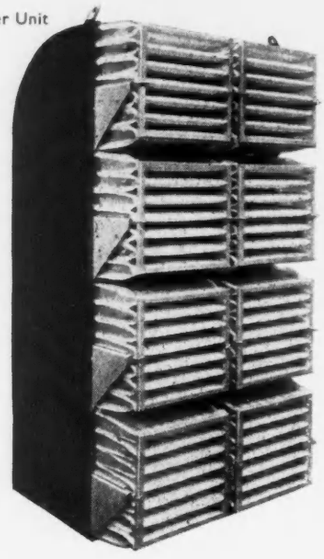


VISCO 'KM' Type Oil-Wetted Air Filter

WET or DRY

VISCO 'MV' Dry Type Air Filter Unit



VISCO Air Filters devour dust. Air filtration economics can be solved the VISCO way. Both types are simple, robust, reliable, efficient. The oil-wetted filters operate in such a way that collected dust in turn helps to collect further. Each cell has tremendous capacity and is easily cleaned. VISCO 'MV' dry type filters are over 98% efficient. Each unit will deal with up to 1,000 c.f.m. Throw-away filter elements are easily changed after several hundred hours active life. Full information from THE VISCO ENGINEERING CO. LTD., STAFFORD ROAD, CROYDON. Telephone: CROydon 4181.

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Air Filters

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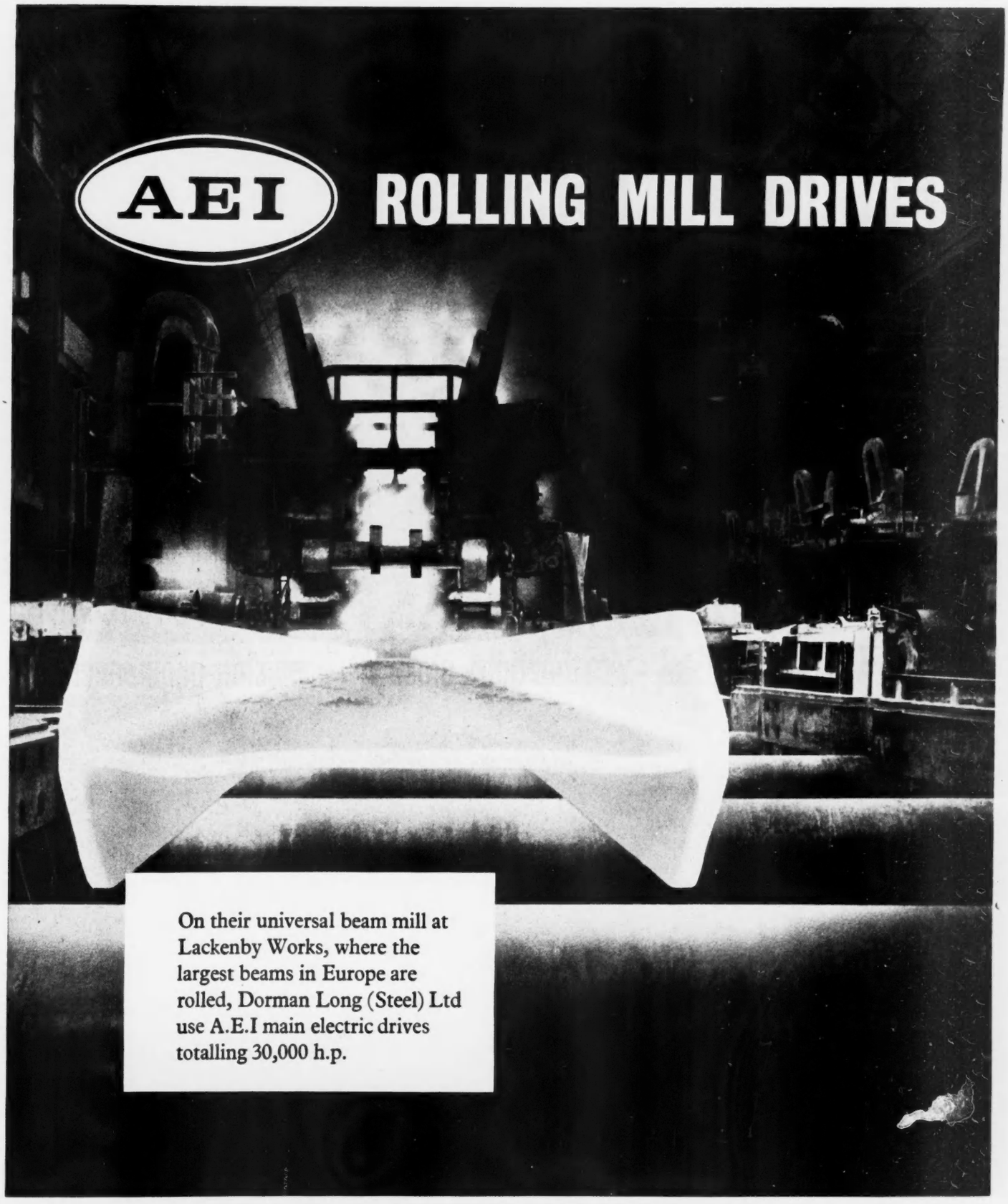
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On their universal beam mill at Lackenby Works, where the largest beams in Europe are rolled, Dorman Long (Steel) Ltd use A.E.I main electric drives totalling 30,000 h.p.

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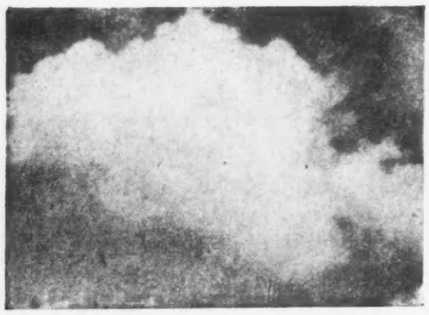

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VENTILATORS

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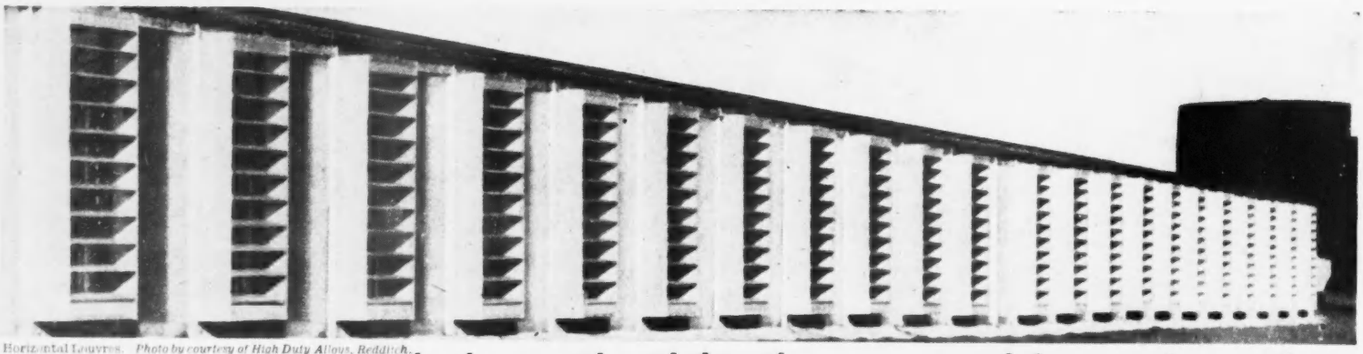
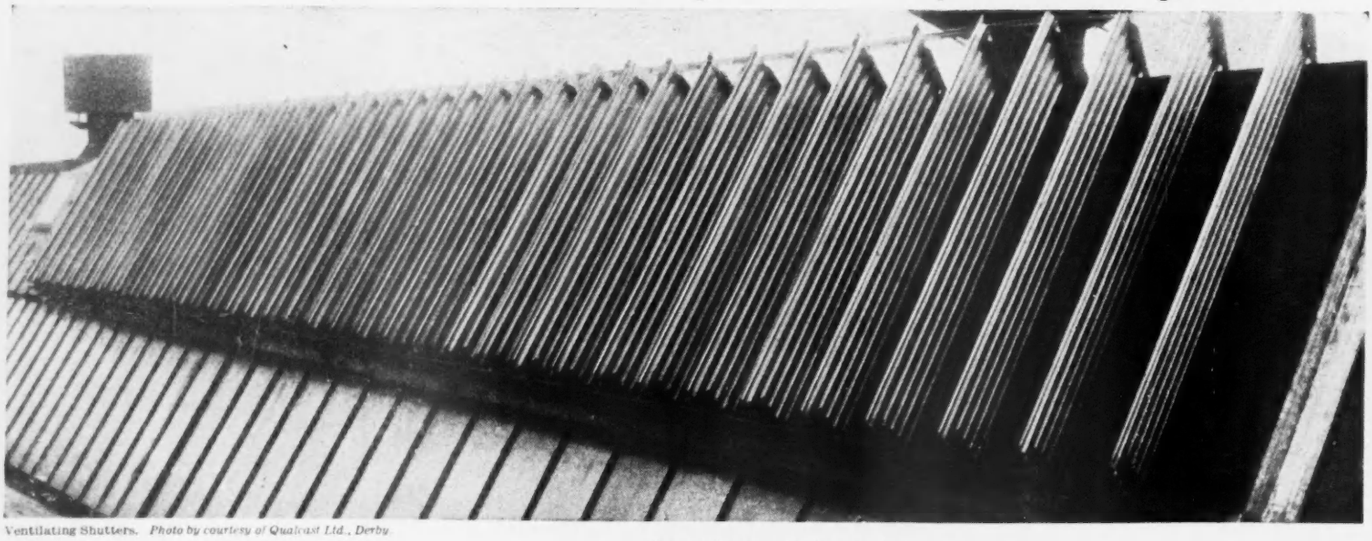


Horizontal Louvres. *Photo by courtesy of High Duty Alloys, Redditch.*

practical - weathertight closure - precision-engineered



Ventilating Shutters. *Photo by courtesy of Qualcast Ltd., Derby.*

Roof Slope and Vertical Louvres
Continuous Ridge Ventilators
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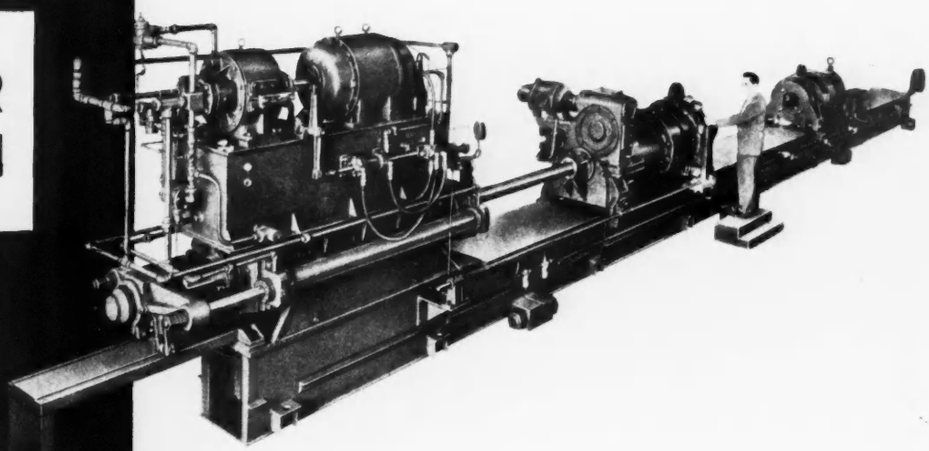
FARMER NORTON

100 Ton Hydraulic Stretch Straightener



Illustrated is a typical 100 Ton Hydraulic Stretch Straightener with 4-jaw detwisting head. Hydraulic stretching and detwisting Machines are available in all sizes and capacities.

WITH FOUR-JAW DETWISTING HEAD

Built under exclusive licence from Sutton Engineering Company, Pittsburgh, U.S.A. by

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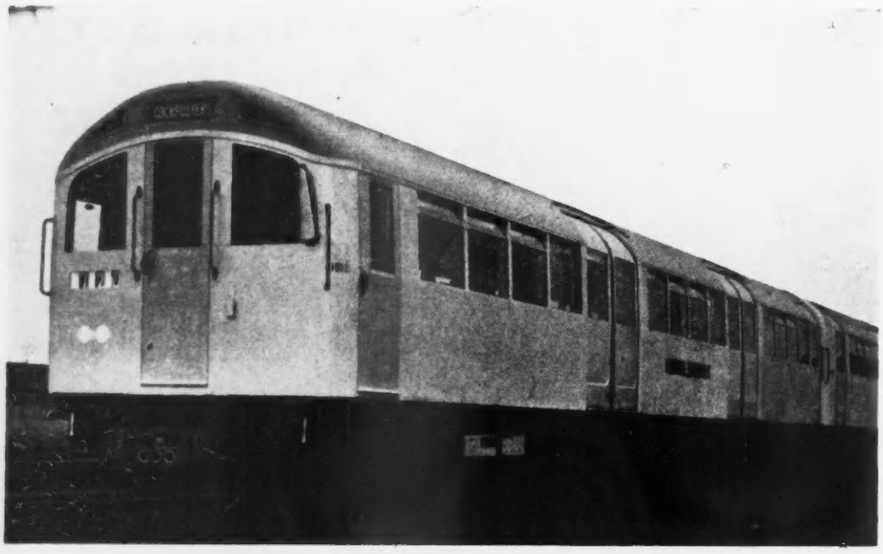

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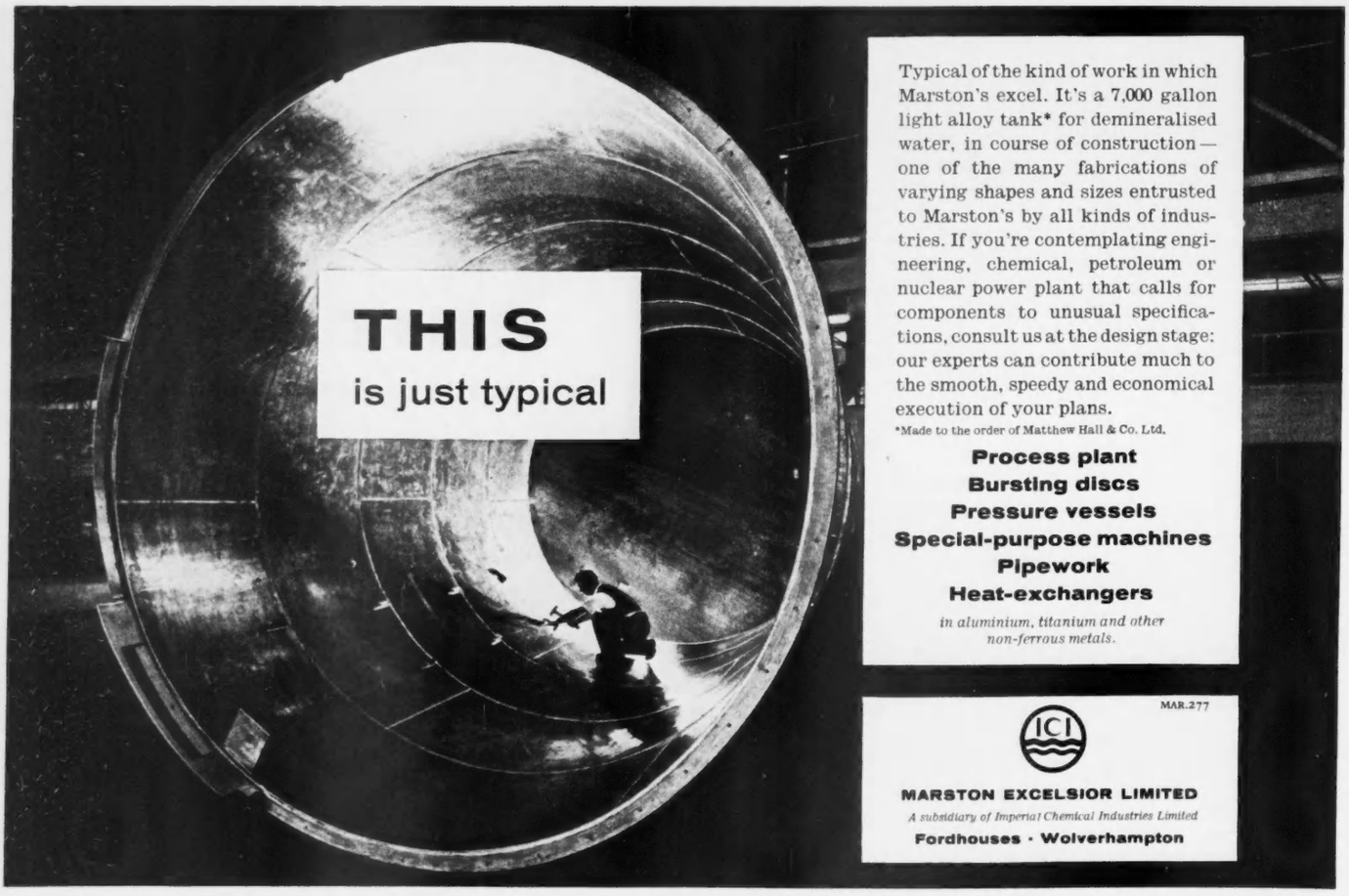

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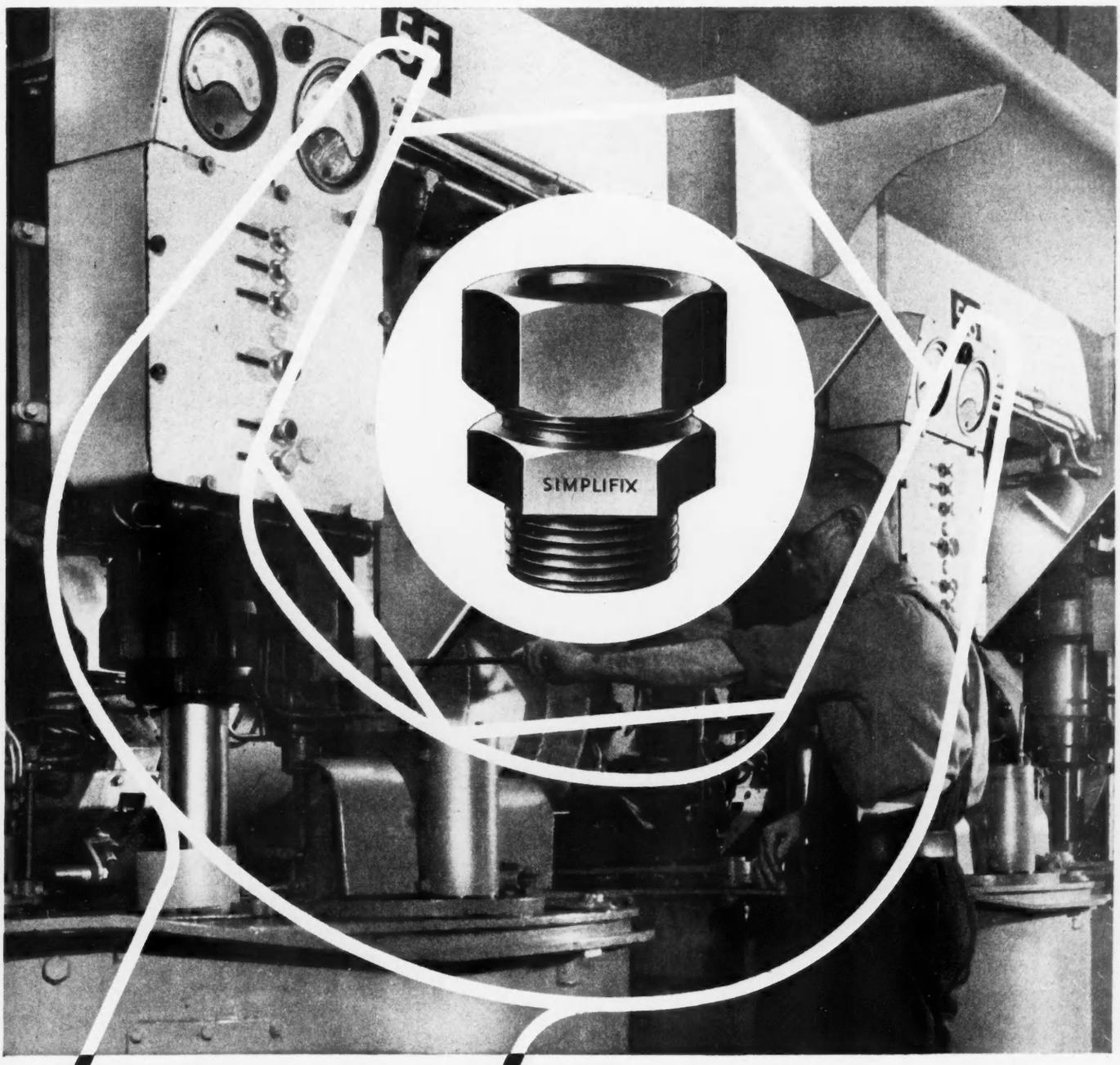

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Simplifix—the sure and simple compression coupling for copper pipe. Perfect joints with almost all kinds of tubing, including those with very thin walls. No work to do on the pipe. Simply tighten the nut—the anti-friction washer prevents the pipe twisting. Manufactured since 1930, still the best. Millions in use. Made in sizes to suit tubing from $\frac{1}{8}$" to 2" O.D., in a wide range of interchangeable standard fittings. Non-standard fittings also made to order. Let us send you the Simplifix catalogue.

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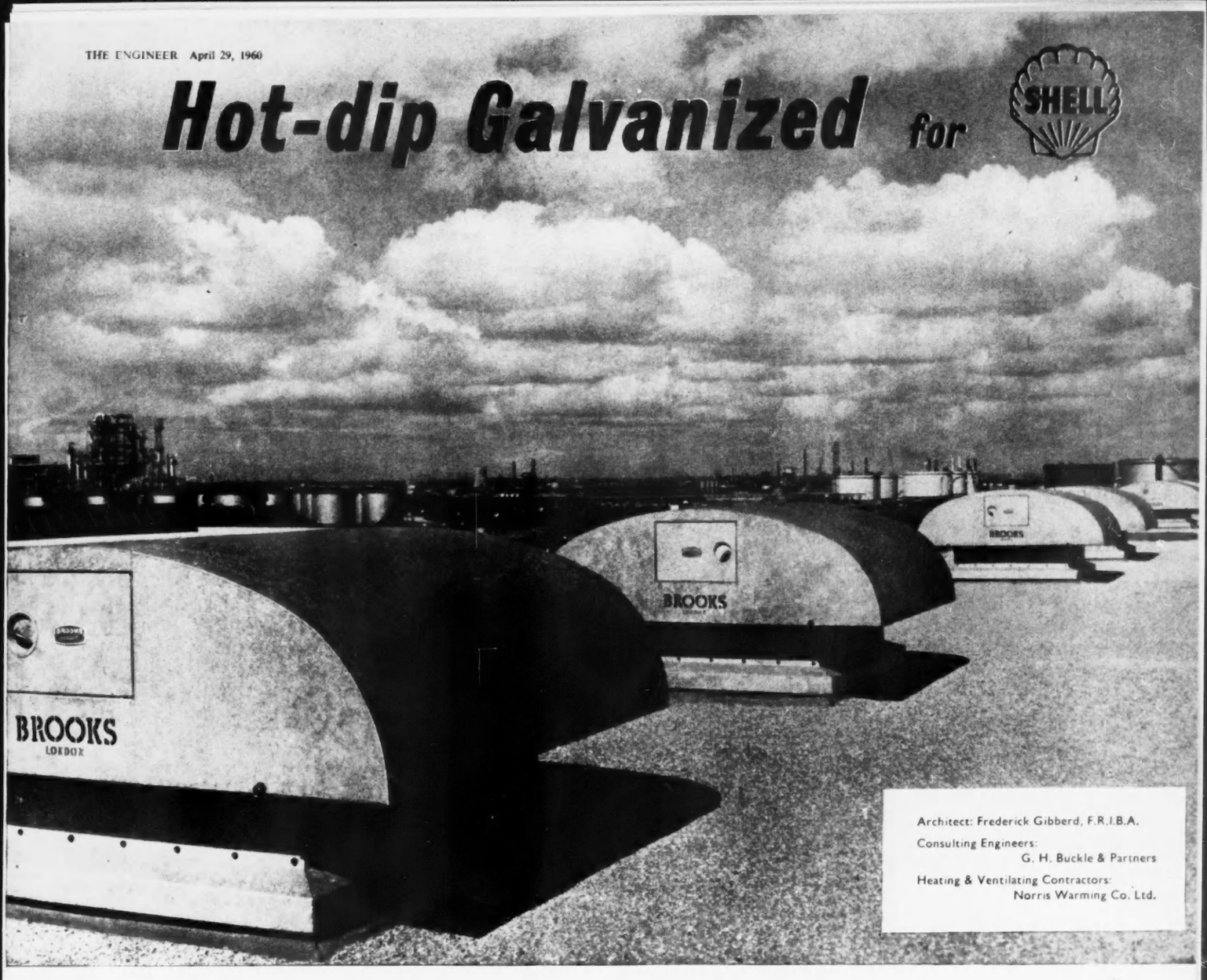

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Consulting Engineers: G. H. Buckle & Partners
Heating & Ventilating Contractors: Norris Warming Co. Ltd.

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fan-powered

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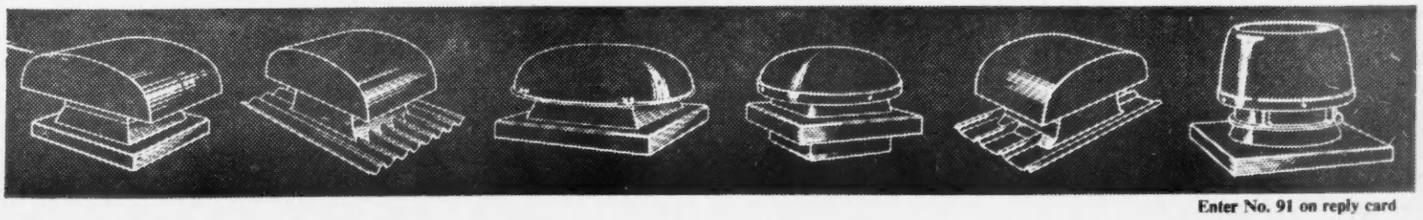

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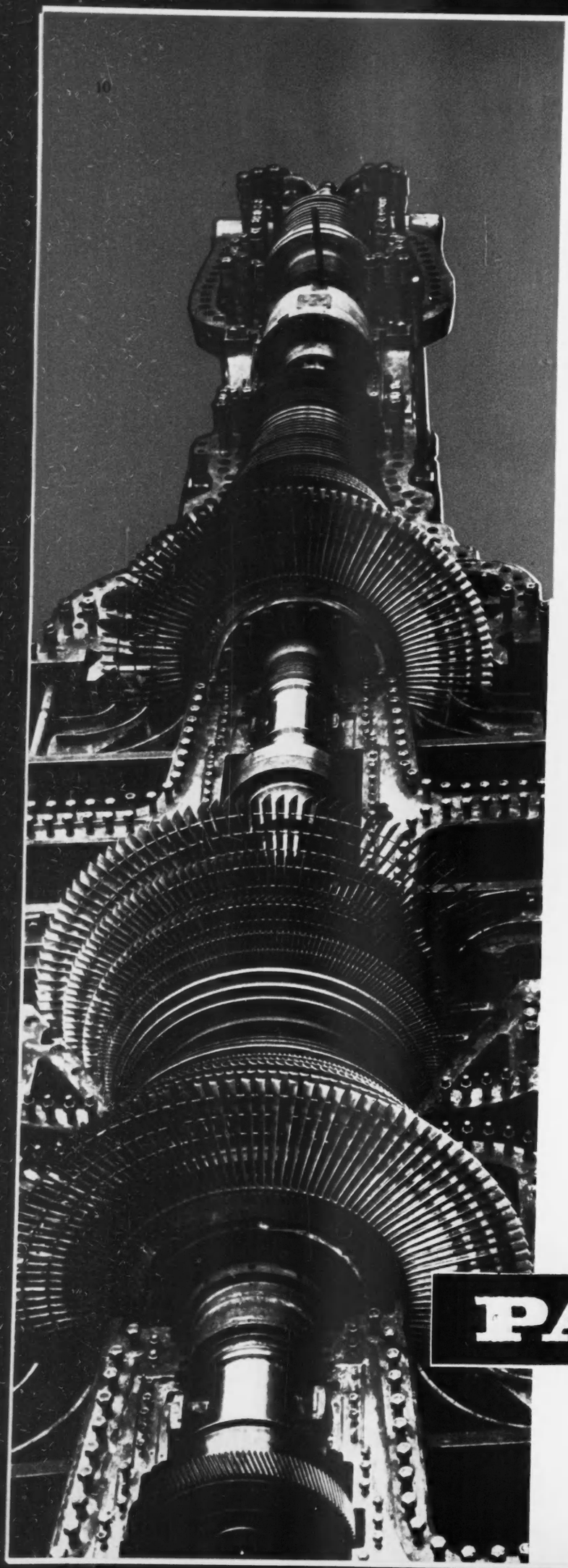
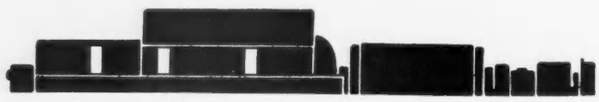
BRITAIN'S WIDEST RANGE OF POWERED VENTILATION UNITS



PARSONS



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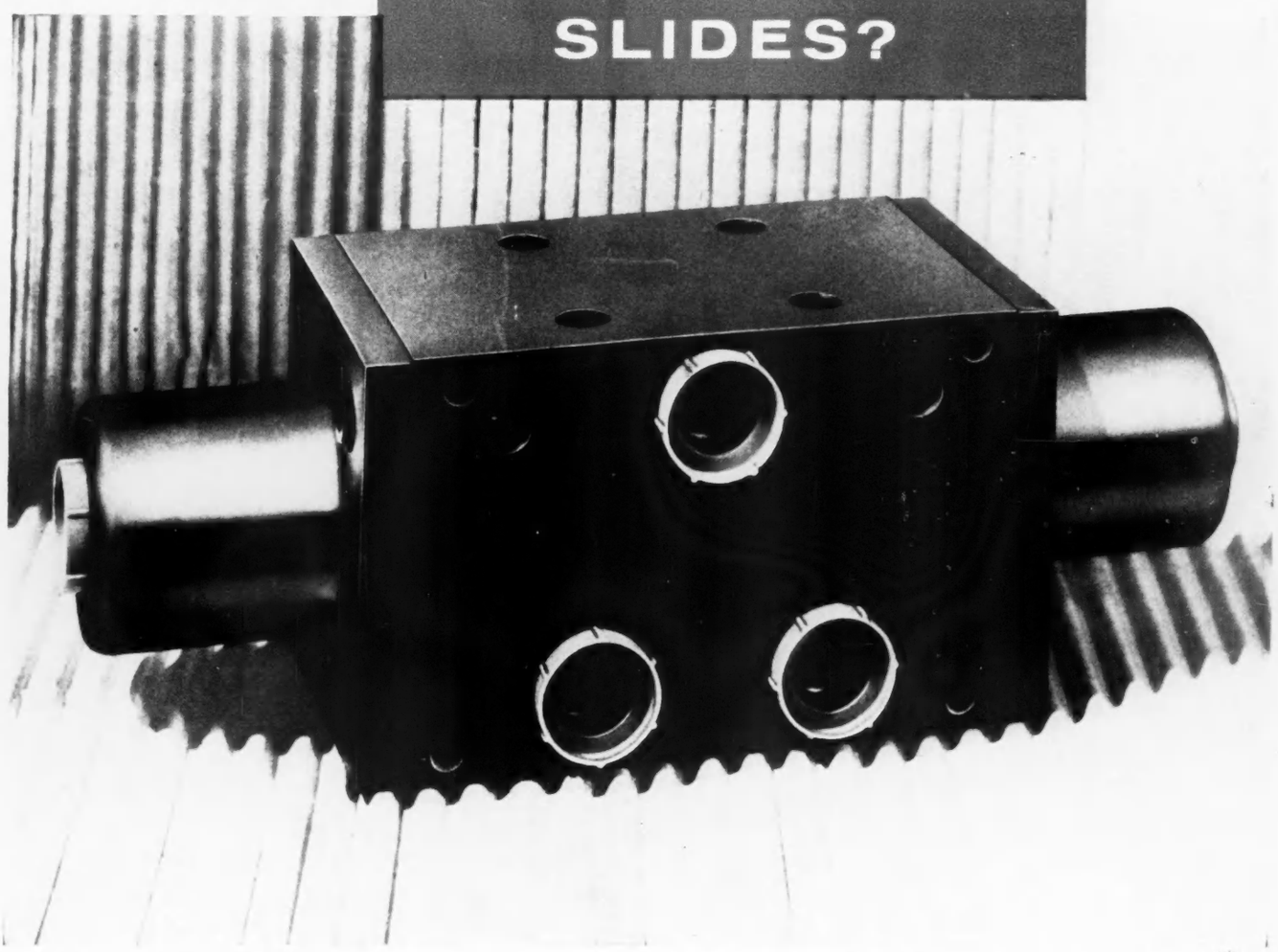

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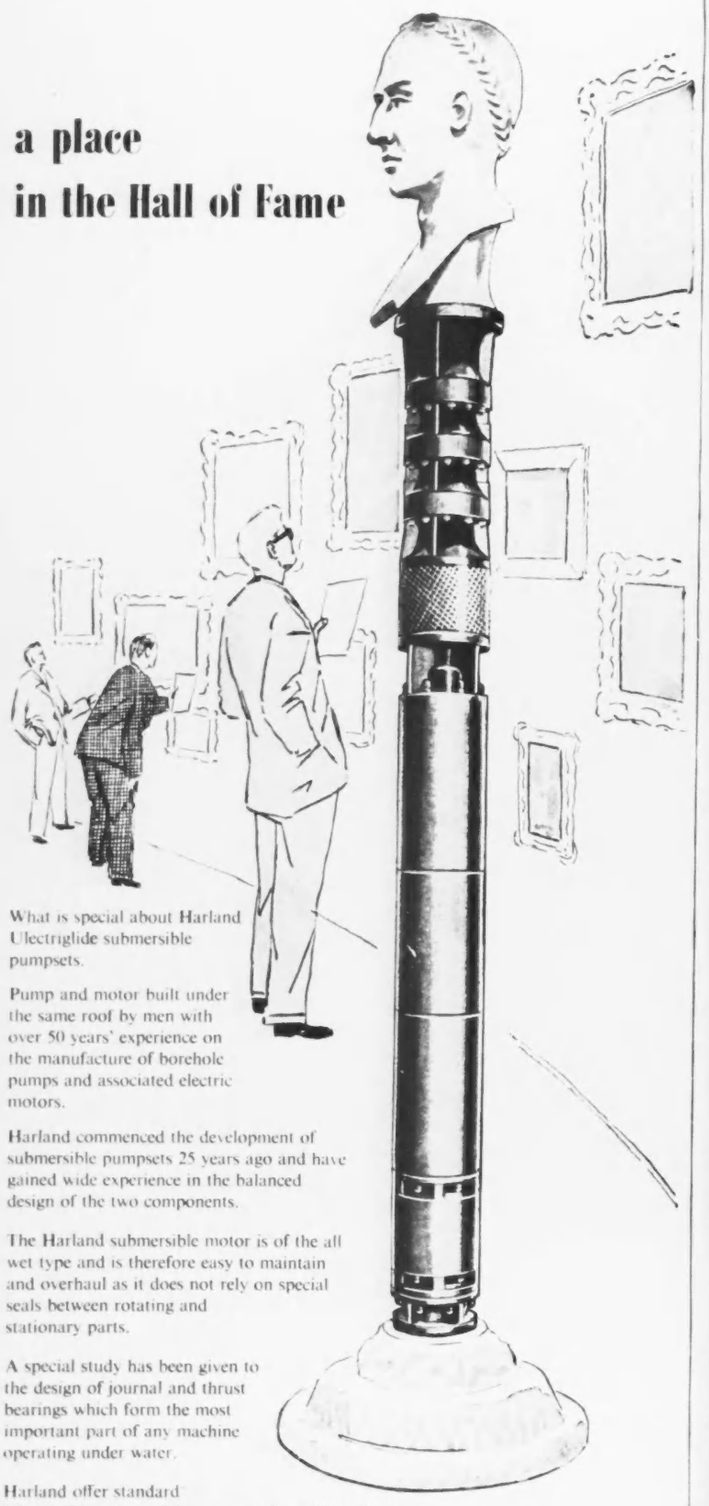

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In the field of separation and collection of dust we offer complete equipment with the Buell High Efficiency Cyclones fabricated in various types of construction to meet the particular conditions dictated by the requirements of many industries. Buell Drying Plants are well known for their application to the drying of a wide range of materials. It is our policy to make a special study of the various problems involved before selecting the design of Buell Dryer to suit the individual case.

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Araldite *epoxy resins*

Araldite is a registered trade name

Araldite epoxy resins are used

- **for casting high grade solid insulation**
- **for impregnating, potting and sealing electrical windings and components**
- **for producing glass fibre laminates**
- **for producing patterns, models, jigs and tools**
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- **as protective coatings for metals, wood and ceramic surfaces**
- **for bonding metals, ceramics etc.**

May we send you further details?

CIBA (A.R.L.) LIMITED *Duxford, Cambridge · Telephone: 2121*

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ELSWICK & SCOTSWOOD WORKS,
NEWCASTLE UPON TYNE
ENGLAND

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1,200 Ton "British Chaney" Press under construction.
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The press is completely automatic in operation & all its parts are made here, including "Dies".

There are two rows of 50 Ton cranes running, & high up above - the work

Height, about 32 feet above ground, and at least 10 below ground

Five hundred men work - including those alone, when the Ship is not so many in the Works - & many more

Eccentric Gear

Steel casting also made here 1½ Tons

There are Tons "Slings"

TOM DODDS, "Slinger" of 17 shop.

An important man indeed His job is to load, and control all movements of the great cranes

A great deal depends on this mans skill and judgement. He's a Vickers type all right. His father was a crane driver here, & Tom has a son in the Research dept.

"TUNES"

The shop is about ¼ mile long and 70 feet high, and there are others like it.

This is the way that transmits power from the drive shaft to the moving parts of the press. It is installed eight feet below the surface

The shop cat, that everybody feeds but nobody owns!

NEXT COMMISSION. AIRCRAFT

"The VANGUARD," Weybridge Works, SURREY.
(Nice & near home!)

Mr. Terence Cuneo has been commissioned by Vickers Limited to produce a series of drawings giving his impressions of the immense resources and production capacities of the Vickers Group. Mr. Cuneo's original pencil sketch and notes for his subject, made on the spot and reproduced here, convey in a particularly vivid manner the size and capabilities of the Elswick shops.

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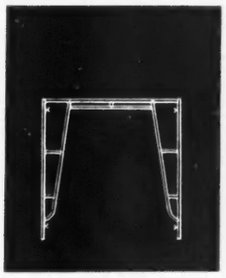

Every engineer who saw this advertisement which we reproduce on the opposite page by the kind permission of Messrs Vickers-Armstrongs must have been impressed, as we ourselves were, by the vigour and realism of Terence Cuneo's drawing For us it held an added interest. Although we supply many large firms (Vickers-Armstrongs among them) with our unit frame works staging we do not always know in exactly what way it will be used, so that it was with particular pleasure that we noted its use in the erection of the Power Press at Vickers-Armstrongs (Engineers) Limited Elswick Works at Newcastle

The illustration emphasises in a rather different manner a point which we have been making for some time—the versatility and suitability of Safway Unit frames both for initial erection and maintenance work for engineering and all industrial applications.

STERLING SAFWAY

Unit Frames for temporary structures. Ships staging Builders access and support Scaffolding.

PROPRIETORS, STERLING FOUNDRY SPECIALTIES LTD. BEDFORD, ALSO LONDON, JARROW, EDINBURGH, AND BRISTOL

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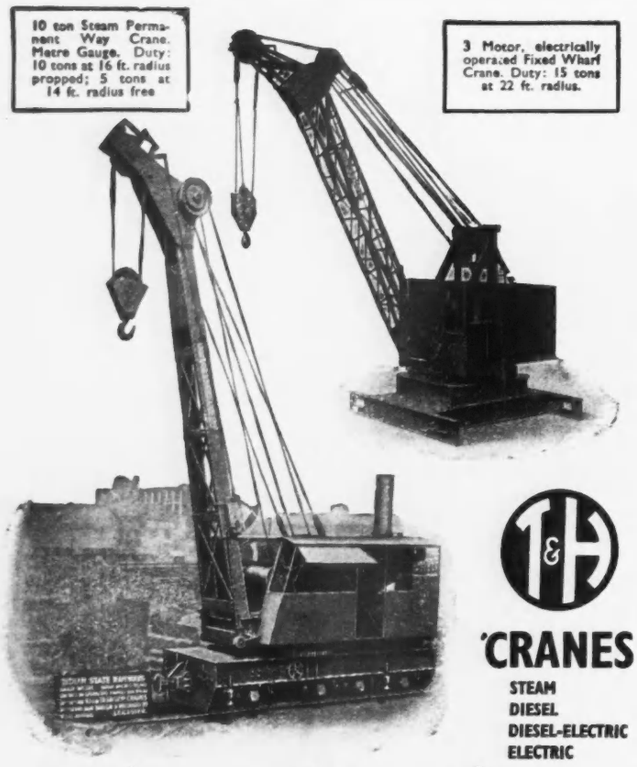

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'CRANES

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DIESEL-ELECTRIC
ELECTRIC

TAYLOR & HUBBARD LTD
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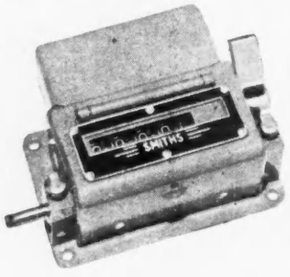
The meaning of SMITHS in Production Planning

Efficient production planning aims at eliminating *all* wastage. This means, in machine control, substituting precision methods for the guesswork of manual ones with their attendant material and time wastage when slowing down.

SMITHS Predetermined Counters operate at an *exact count;* they offer you reliable precision control. With a speed of count as high as 4,000 per min., these strong, robust instruments are ideal for applications requiring counts of repetitive lengths or numbers—cloth lengths, coil windings, packaging and batching sequences, for example.



Can be set to any number between 1 and 99,999

FOR IMMEDIATE DELIVERY

Write now to

SMITHS INDUSTRIAL INSTRUMENT DIVISION

Chronos Works, North Circular Road, London, N.W.2 Telephone: GLAdstone 1136

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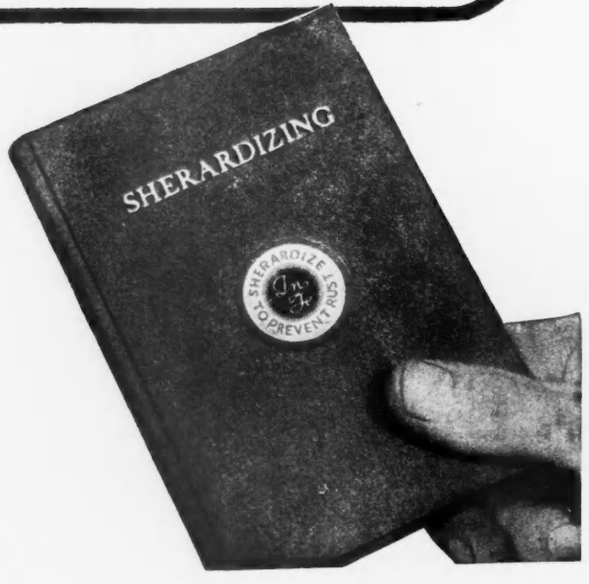

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ZINC ALLOY RUST PROOFING Co. Ltd.

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Telephone: Wolverhampton 27531 (5 lines)

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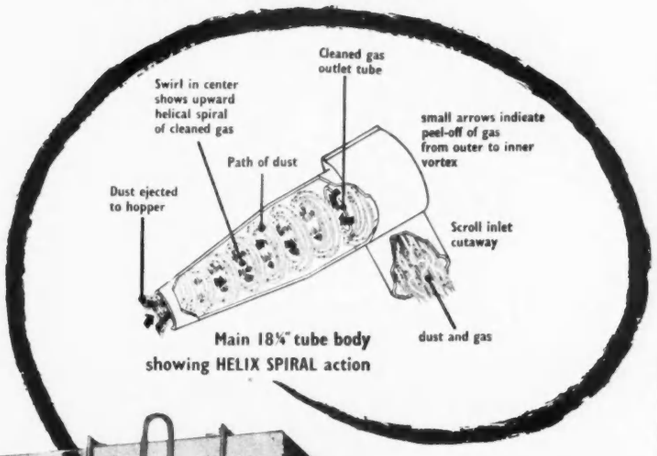
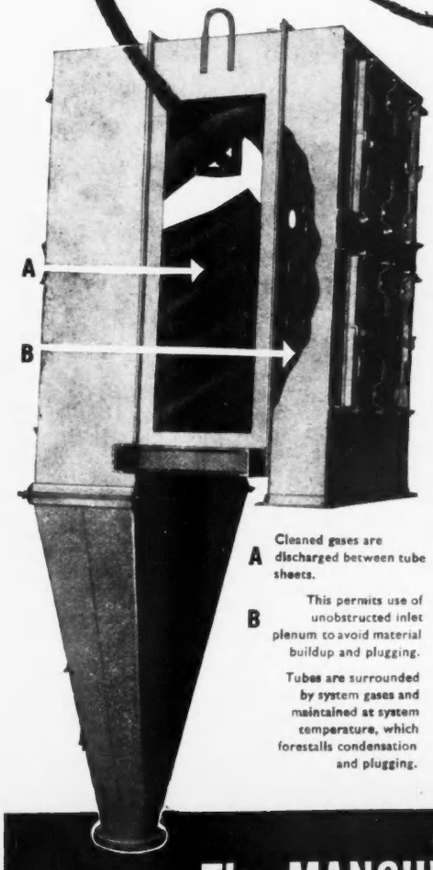
MANCUNA - DUSTEX pays its way

- *In profitable product recovery*
- *In trouble-free dust control*


Cleaned gas outlet tube
Swirl in center shows upward helical spiral of cleaned gas
small arrows indicate peel-off of gas from outer to inner vortex
Path of dust
Dust ejected to hopper
Scroll inlet cutaway
dust and gas
Main 18¾" tube body showing HELIX SPIRAL action



A Cleaned gases are discharged between tube sheets.

B This permits use of unobstructed inlet plenum to avoid material buildup and plugging.

Tubes are surrounded by system gases and maintained at system temperature, which forestalls condensation and plugging.

A REVOLUTIONARY NEW UNIT-CAST DESIGN

This cutaway miniature cyclone tube from the tube bank of the new Mancuna-Dustex Collector shows why efficiency is so high and maintenance negligible. The scroll inlet establishes a velocity which is maintained through its powerful vortex—the dust travelling downward in an outer vortex to the hopper while the cleaned air moves upward in an inner vortex to the outlet tube for discharge between tube sheets. D-584 tubes are available in abrasion-resistant cast iron, non-sparking cast aluminium or stainless steel. Note the one-piece cast tube design with minimum ¼" wall thickness which increases tube life and performance.

The MANCUNA - DUSTEX D-584 MINIATURE CYCLONE COLLECTOR

MANCUNA ENGINEERING LIMITED,
Denton, Manchester. Tel: DENton 3965 (5 lines)
London Office: 59, Victoria Road, Surbiton, Surrey. Phone: Elmbridge 9793
SPECIALISTS IN GAS CLEANING AND DUST TECHNOLOGY.

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OLYMPIA, LONDON

June 25—July 8 *(Sundays excepted)*

9.30 am—6 pm

Make sure you visit the greatest engineering event of the year — The International Machine Tool Exhibition . . . No-one concerned with quantity production — whether in technical, administrative or operative capacity — can afford to miss this vast and truly comprehensive show at Olympia, London. It summarizes the best of contemporary production techniques; it shows the shape of things to come!

Machine Tools
Engineers' Small Tools
Gauges and Measuring Equipment
Testing Equipment
Electronic Control Gear
Presses and Power Hammers
Woodworking Machinery
Heat Treatment Plant

Here's your opportunity to see them all under a single roof — to see many of them powered and in operation — to discuss their application to your own production problems with the world's best-informed production experts.

International Machine Tool Exhibition 1960

Organized by The Machine Tool Trades Association, Brettenham House, Lancaster Place, London, W.C.2.

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-let E.P.E. solve them for you quickly
In these days of AC it is not always easy to get DC motors and generators quickly and at a reasonable price. Fortunately, EPE specialise in DC equipment, bringing years of experience to bear on the subject, so that one can always be sure of DC motors and generators, of any enclosure, at competitive prices, on short delivery. EPE are always happy to help solve DC problems, too.
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'Grams: Torque 'Phone Birmingham
London Office: 421, Grand Buildings, Trafalgar Square, W.C.2. 'Phone: Whitehall 5643 and 7963

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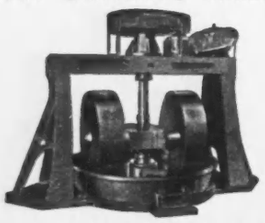
TRADE Smedley MARK
PAN GRINDING MILLS



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THE TORNADO WAY
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For a very reasonable outlay you can protect your staff from dangerous fumes, grit and dust, by using the :
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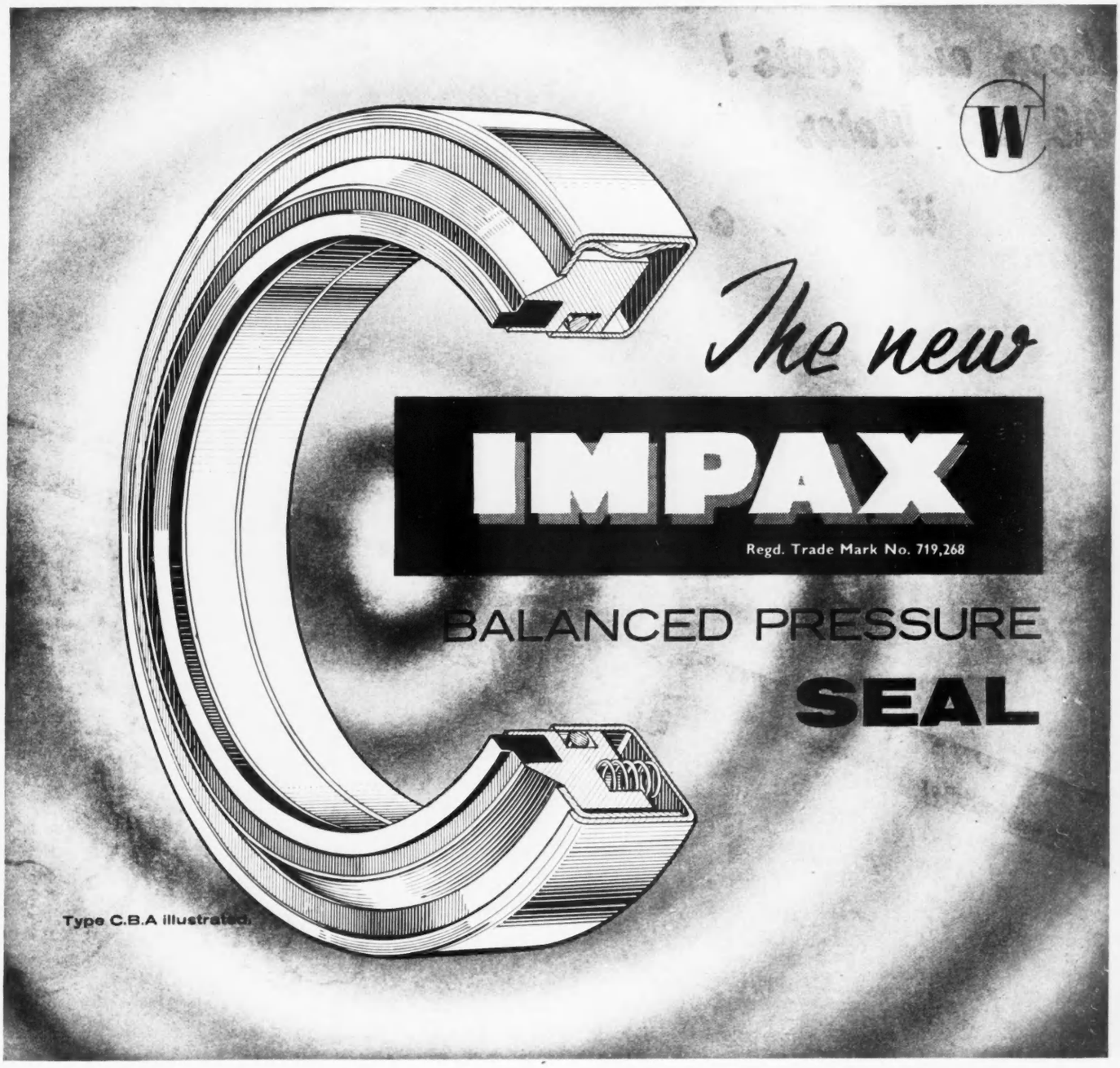

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Specially designed and produced for the purpose – Weston IMPAX Seals are established for use on high speed rotating shafts, coupled with high fluid temperatures and pressures. A new series has been developed, using the most advanced materials to keep pace with the quickening tempo of modern machine operation.

Send for new Catalogue now to: Complete range of Seals available.

CHARLES WESTON & CO. LTD.

Irwell Bank Works, Douglas Green, Pendleton, Salford, 6

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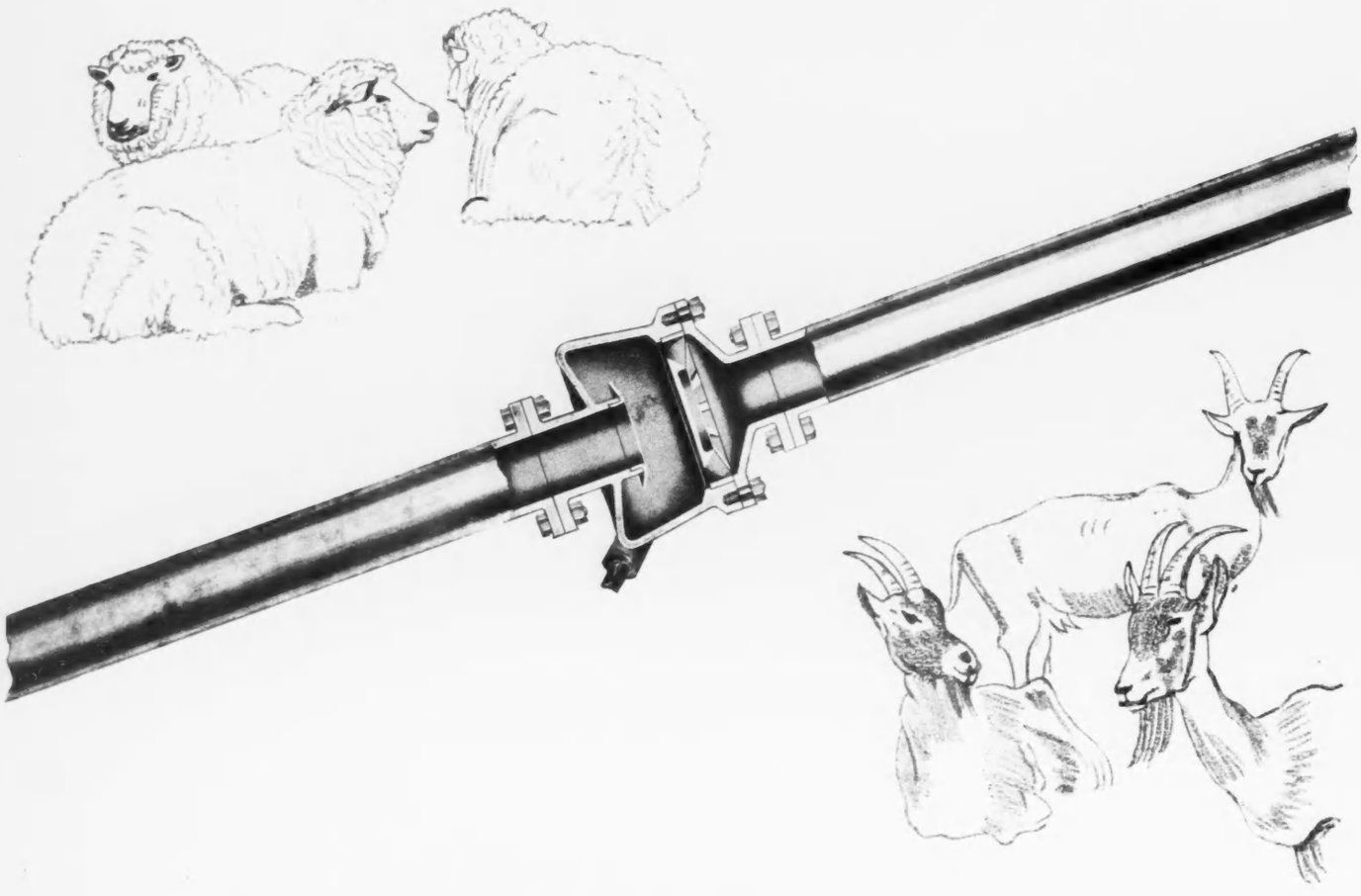
Sheep and goats!
Oil and Water!
it's all a matter of separation



We cannot deal with sheep or goats, but the 'Supreme Vortex' pipe line separator is unsurpassed for separating . . . .

Moisture **and oil drops from compressed air**
Moisture **from steam**
Dirt particles **from gases**

carruthers
SEPARATOR DIVISION

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Telephone: East Kilbride 20591
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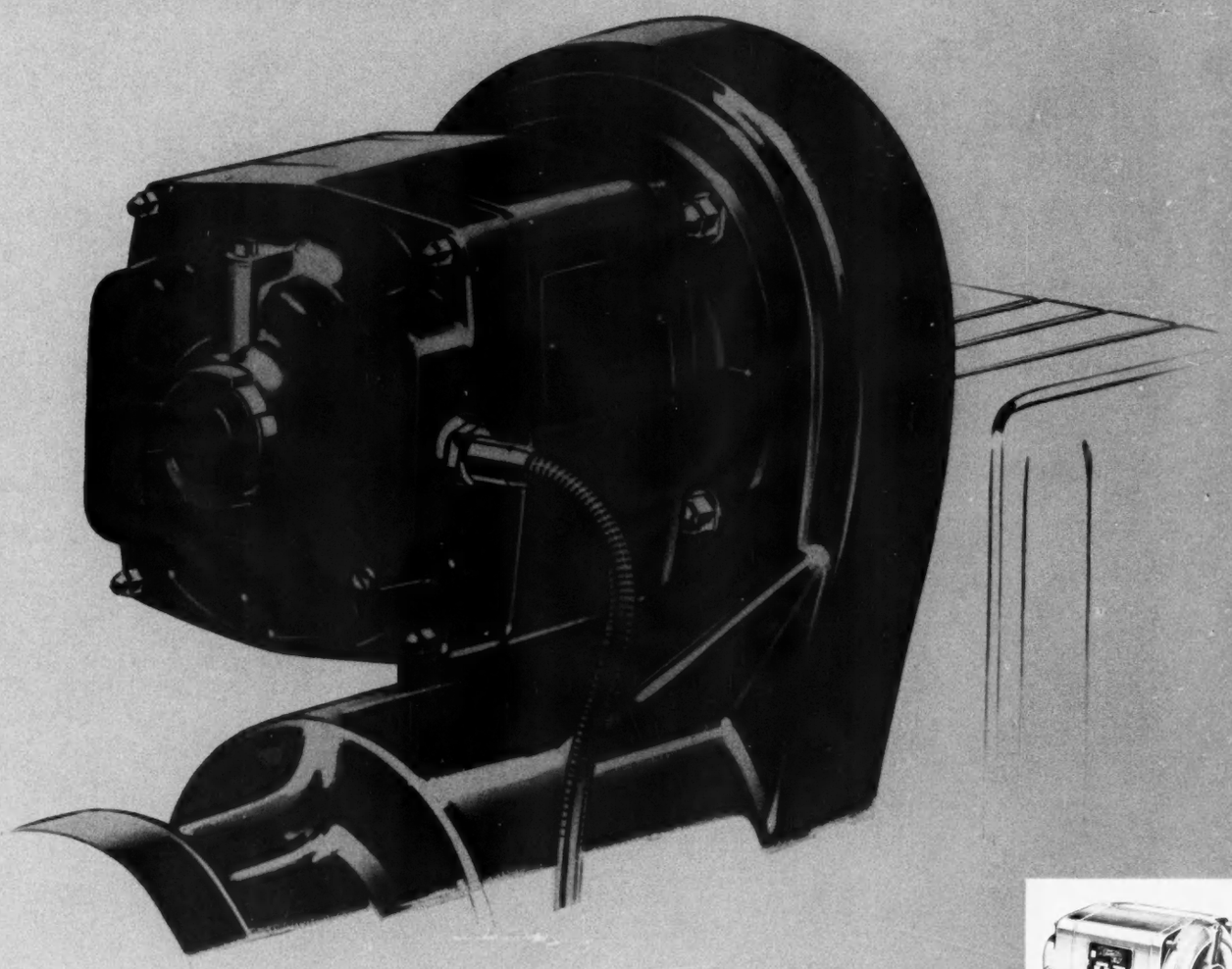
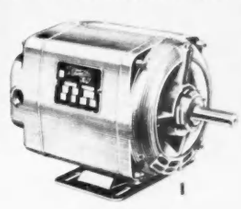
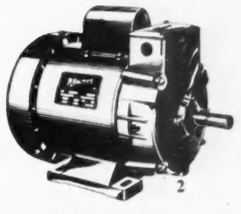
Newman

MULTI-RANGE MOTORS

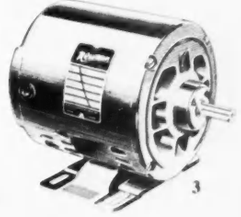




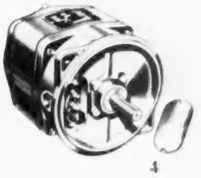
1 Type 'ELE' 1/16-1 h.p. Standard Totally Enclosed or Drip-Proof, Foot, flange or resilient mounting, Single- or three-phase. Frame '56' Dimensions.



2 Type 'BK' 1/3-3 h.p. Totally enclosed. Foot, flange or face mountings. Single- or three-phase. Frame '66' Dimensions.



3 Steel-Frame type 1/8-1 h.p. Drip-Proof. Foot, flange or resilient mountings. Single- or three-phase. Frame '56' Dimensions.



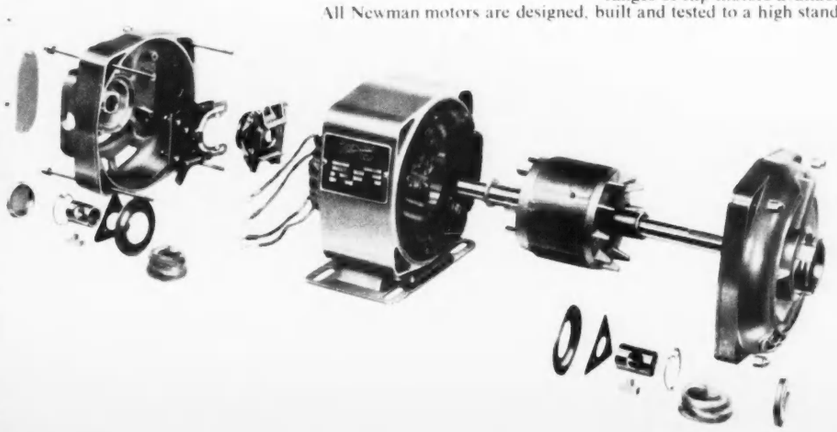
4 Type 'ELE' 1/16-1 h.p. Oil Burner Motors. Frame '56' Dimensions.

Nº1 Fractional h.p. motors

The Newman range of fractional horsepower motors comprises three basic types: the type 'ELE' in a well styled die-cast aluminium "square" frame—a quality motor in every sense; the steel frame type in the conventional round style—designed for economy and truly rugged and reliable; the Frame '66' type is an exceptionally compact cast-iron frame—bridging the gap economically between fhp motors and the larger industrial types.

These three types, with their variations in mountings, windings and frame dimensions, form the basis of one of the most comprehensive ranges of fhp motors available today.

All Newman motors are designed, built and tested to a high standard of quality.



Newman

Fractional h.p. motors at work

The field of application for Newman fhp motors ranges from industrial pumps through a host of domestic appliances to agricultural equipment and precision machine tools, and it is so vast that even this kaleidoscope of such applications cannot include them all.

1 '78' Drilling Machine—by courtesy of Kerry's (Engineering) Co. Ltd.—Newman 'ELF' motor.

2 Carbide Tool Groove Grinding Machine—by courtesy of Alwood Machine Tools Ltd.—Newman 'ELF' motor.

3 Watts pressure Jet Oil Burner—by courtesy of Watts Automatic Boilers.—Newman 'ELF' motor.

4 'Easiclene' Model E.W.6 Washing Machine—by courtesy of Easiclene Porcelain-Enamel (1938) Ltd. —Newman 'ELF' motor.

5 The 'Welcome' Oil Burner Unit and the Aero 'Silver Flame' Oil Burners—by courtesy of Smith, Blythe Engineering Co. Ltd.—Newman 'ELF' motor.

6 Professional 35mm Cinema Projectors—by courtesy of Rank Precision Industries Ltd., G.B. Kalee Division.—Newman 'ELF' motors.

7 'Tweeny' domestic sink waste disposal unit—by courtesy of Haigh Engineering Co. Ltd., Ross-on-Wye.—Newman 'ELF' motor.

8 The 'Parnall' Tumbler Dryer—by courtesy of Parnall (Yate) Ltd.—Newman 'ELF' motor.

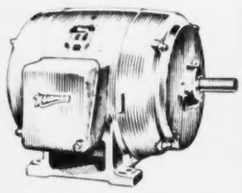
9 The 'KENT' Spin Dryer—by courtesy of Simplex Securities Ltd.—Newman Steel Frame motor.

10 Small Underfeed Stoker Unit—by courtesy of Mirrlees Watson Ltd.—Newman 'ELF' motor.

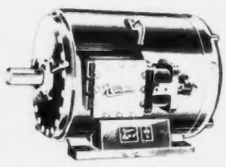
11 Portable spray-painting compressors—by courtesy of Air Industrial Developments Ltd.—Newman 'ELF' motor.

THE NEWMAN RANGE

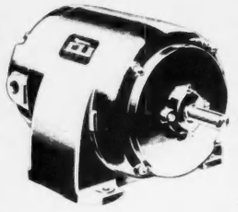
Some of the other types of motors available.



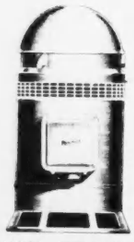
DRIP-PROOF THREE-PHASE MOTORS
NEMA rerated 1–2-150 h.p.



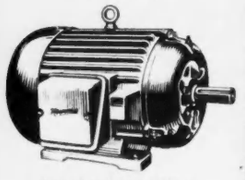
FLAMEPROOF MOTORS STEEL FRAME
(Buxton Certified)
5-100 h.p.
(Available to NEMA Dimensions)



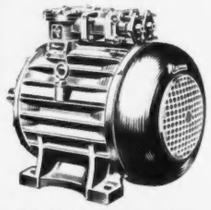
DRIP-PROOF SINGLE-PHASE MOTORS
NEMA rerated 1–2-5 h.p.



VERTICAL HOLLOW AND SOLID SHAFT DRIP-PROOF PUMP MOTORS
NEMA style 'P' bases and to NEMA standard MG 1, 10-300 h.p.



TOTALLY ENCLOSED THREE-PHASE MOTORS
NEMA rerated 1–2-40 h.p.



FLAMEPROOF MOTORS CAST-IRON FRAMES
(Buxton Certified).
British Standards 1–6-50 h.p.

Newman

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601 Cogent

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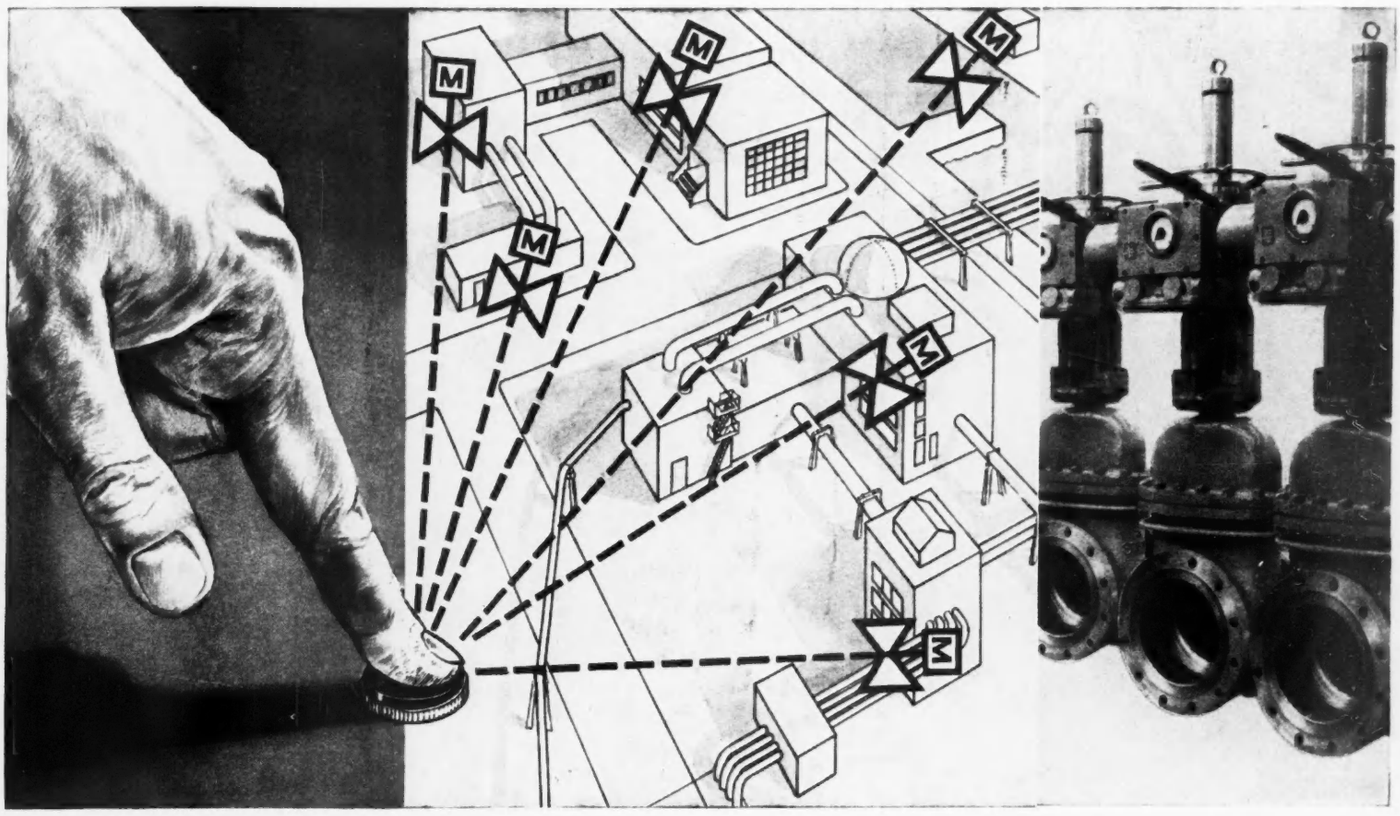
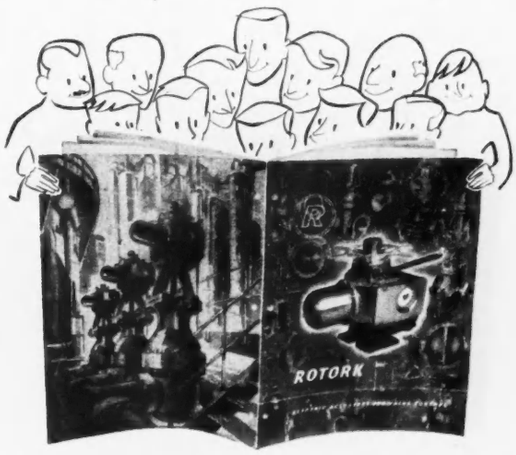


Rotork Actuators mark a turning point in pipework planning

The answer to what has for many years been only a pipe dream, Rotork actuators provide a complete and versatile *all-electric* system of valve motorisation. All sizes and types of valve (and thereby related plant) can be controlled from any distance by a push button or automatically from data such as time, level, temperature, pressure etc.

The automatic reliability of the Rotork system of controlling the flow of liquids and gases reveals hand control as inefficient, uneconomic, human-error-prone and often hazardous. More and more engineers, realising this, are specifying Rotork actuators when planning pipework.



Essential Reading for Pipework Planners

The booklet on Rotork actuators is yours for the asking. Packed with information, it includes an impressive section on the uses to which Rotork actuators are put by Esso, Shell, B.P., Kuwait, Standard Vacuum, Harwell, Dounreay, Richard Thomas & Baldwin, Rolls Royce, C.E.G.B., I.C.I., and many others.

Rotork Actuators for Valve Control

ROTORK ENGINEERING CO. LTD., of BATH, ENGLAND · Tel: 64558

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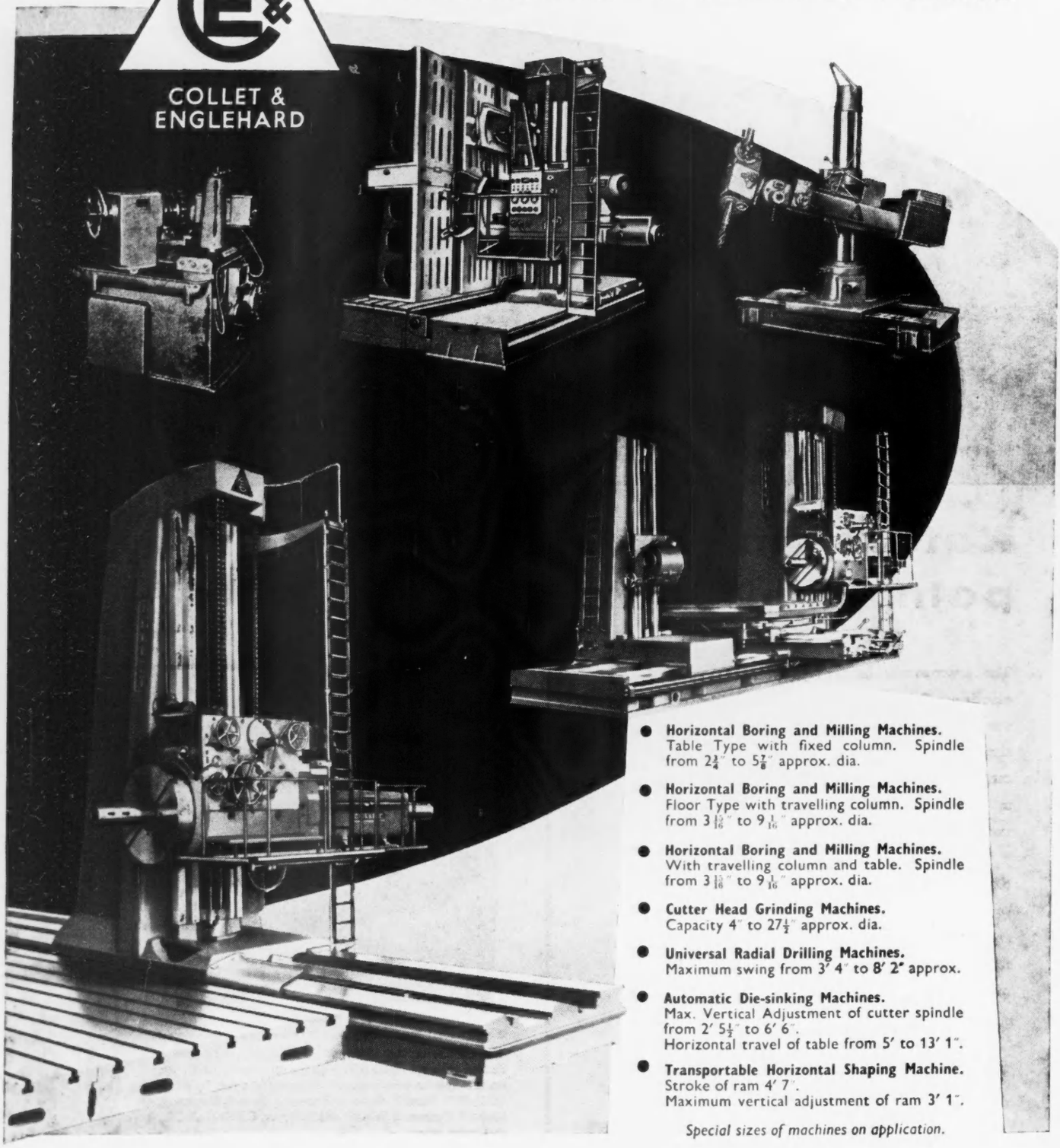
high production
PRECISION MACHINE TOOLS



- **Horizontal Boring and Milling Machines.** Table Type with fixed column. Spindle from 2¾" to 5⅞" approx. dia.
- **Horizontal Boring and Milling Machines.** Floor Type with travelling column. Spindle from 3 15/16" to 9 1/16" approx. dia.
- **Horizontal Boring and Milling Machines.** With travelling column and table. Spindle from 3 15/16" to 9 1/16" approx. dia.
- **Cutter Head Grinding Machines.** Capacity 4" to 27½" approx. dia.
- **Universal Radial Drilling Machines.** Maximum swing from 3' 4" to 8' 2" approx.
- **Automatic Die-sinking Machines.** Max. Vertical Adjustment of cutter spindle from 2' 5½" to 6' 6". Horizontal travel of table from 5' to 13' 1".
- **Transportable Horizontal Shaping Machine.** Stroke of ram 4' 7". Maximum vertical adjustment of ram 3' 1".

Special sizes of machines on application.

WICKMAN Wickman **LIMITED**

FACTORED MACHINE DIVISION, FLETCHAMSTEAD HIGHWAY, COVENTRY

Telephone : Coventry 74821

514 FB1 | 10

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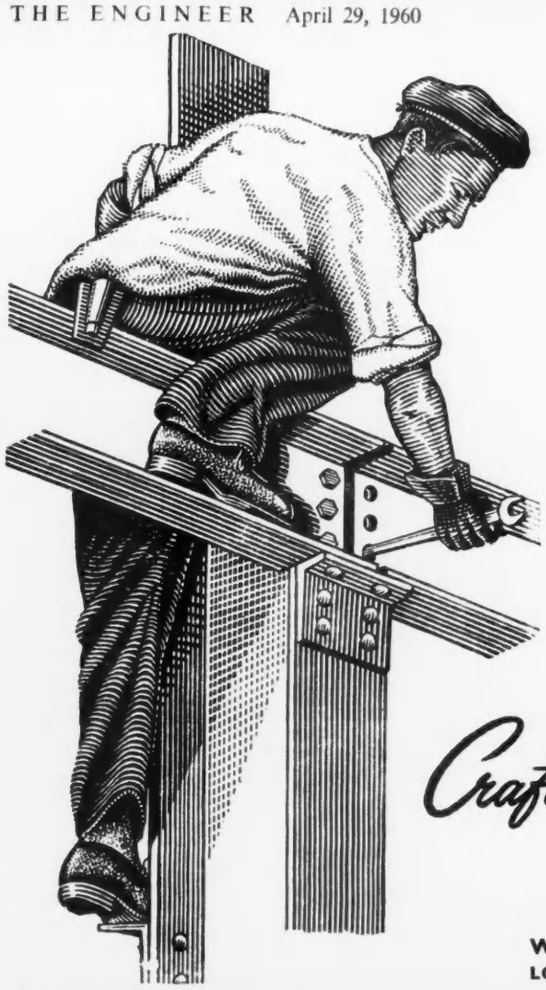

Craftsmanship comes the hard way...

If over 90 years spent in the design, fabrication and erection of structural steelwork means anything—it means you can place this work in our hands knowing it will progress smoothly to completion. Large job or small, we have the resources to handle all your needs. We welcome the opportunity of serving you.

Craftsmen in steel ..

ESTABLISHED 1867

WALKER BROS LIMITED *Structural Engineers*

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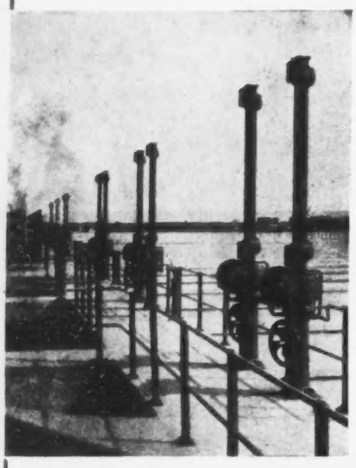

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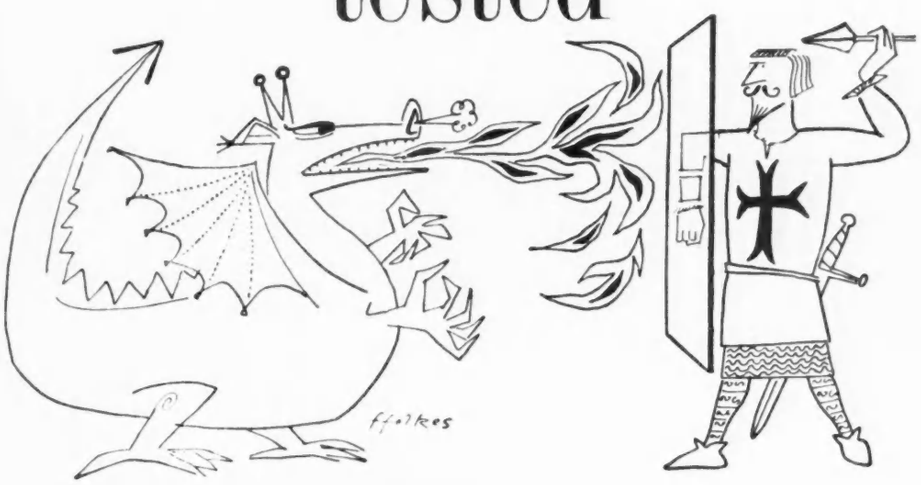

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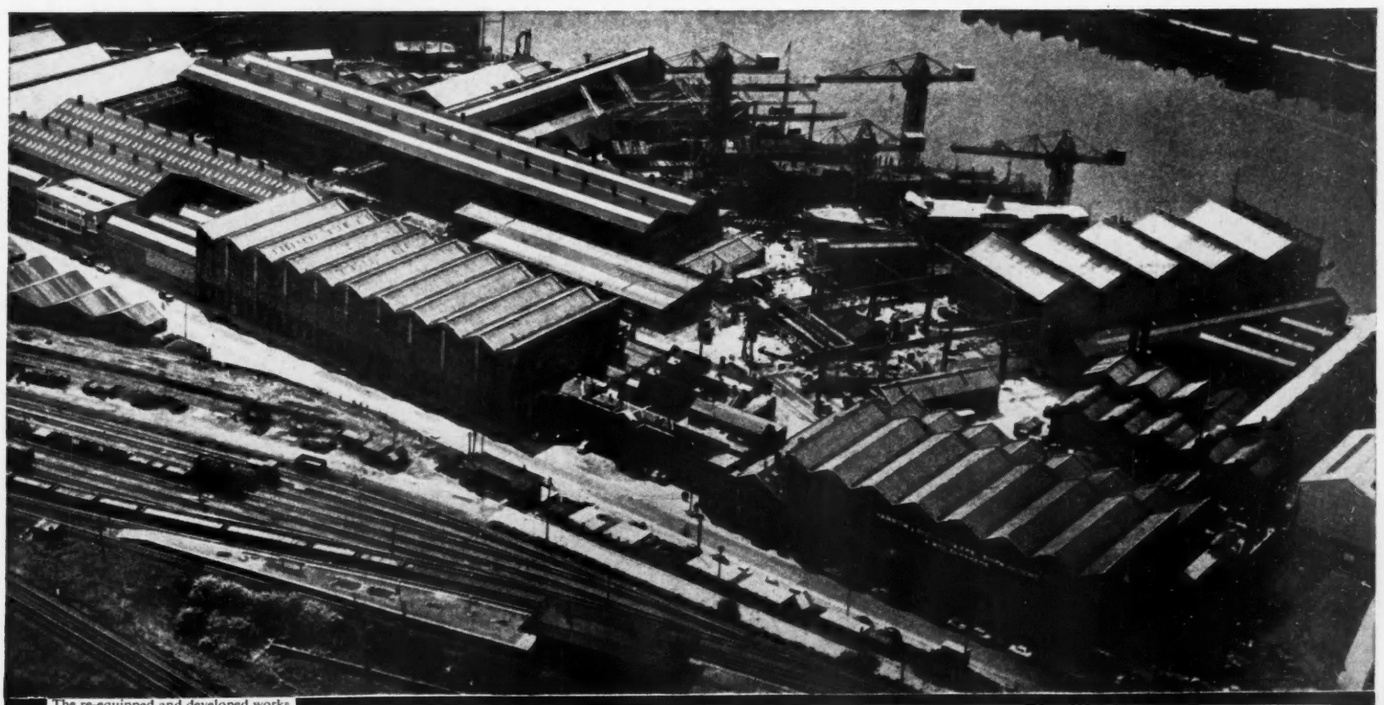

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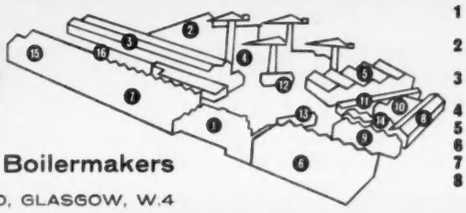

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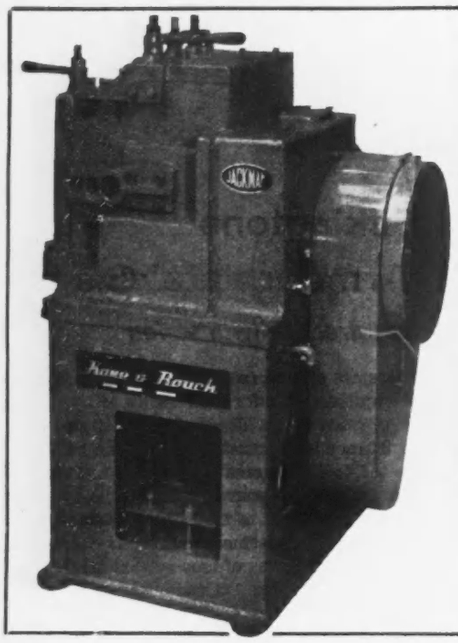

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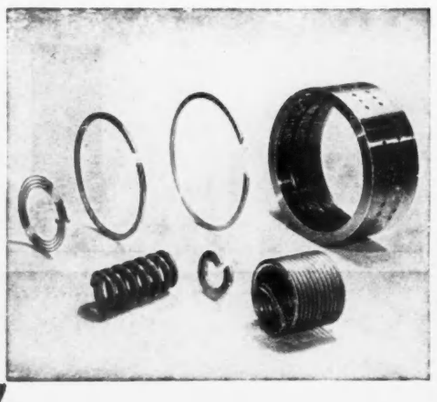

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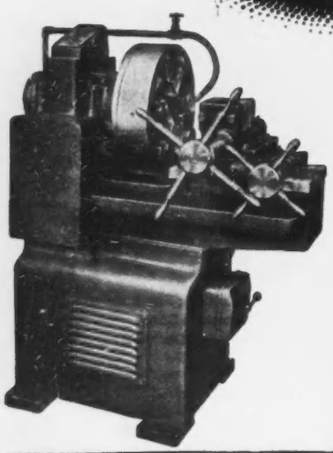

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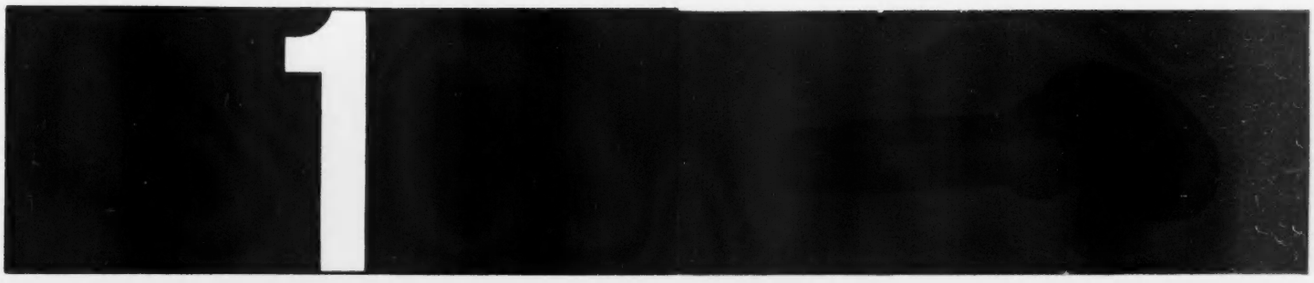

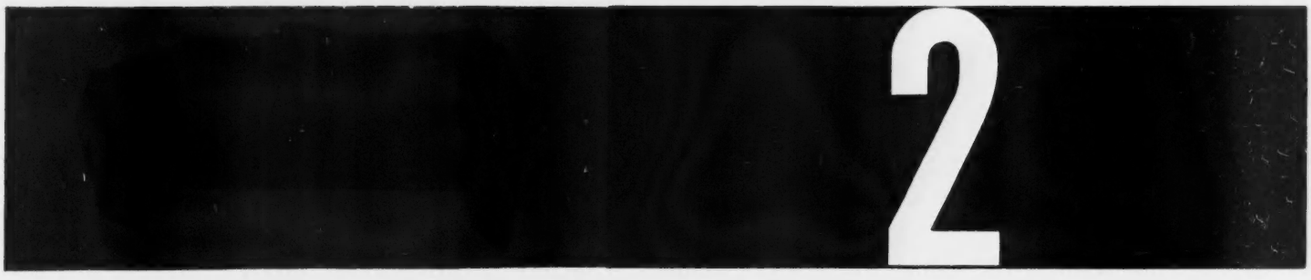

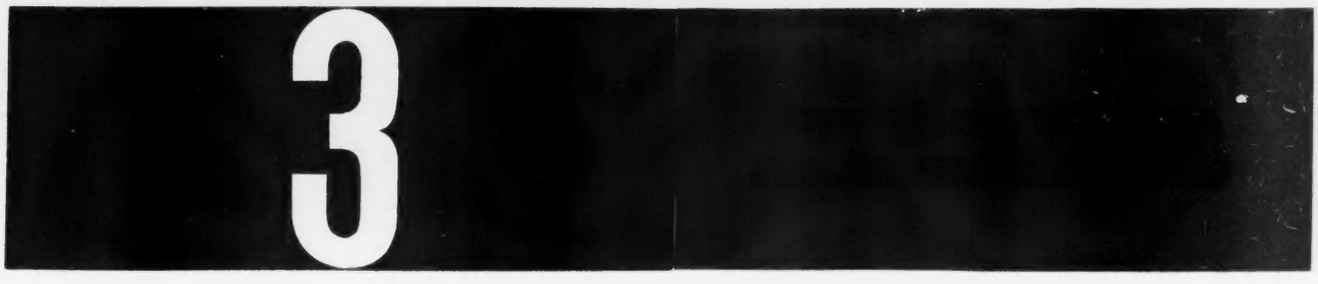

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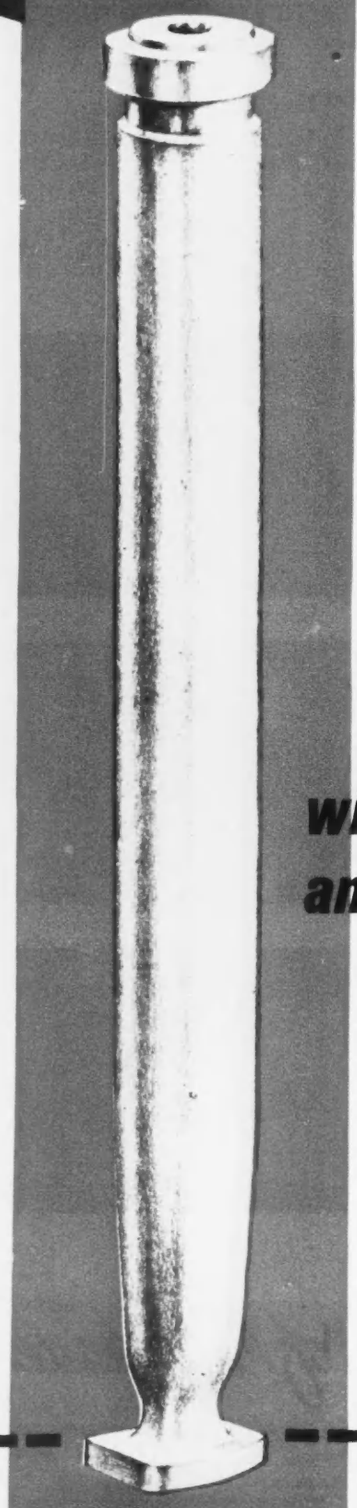
cast in steel at 15% less cost



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with reduced machining and longer life

THE BRITISH STEEL FOUNDERS ASSOCIATION
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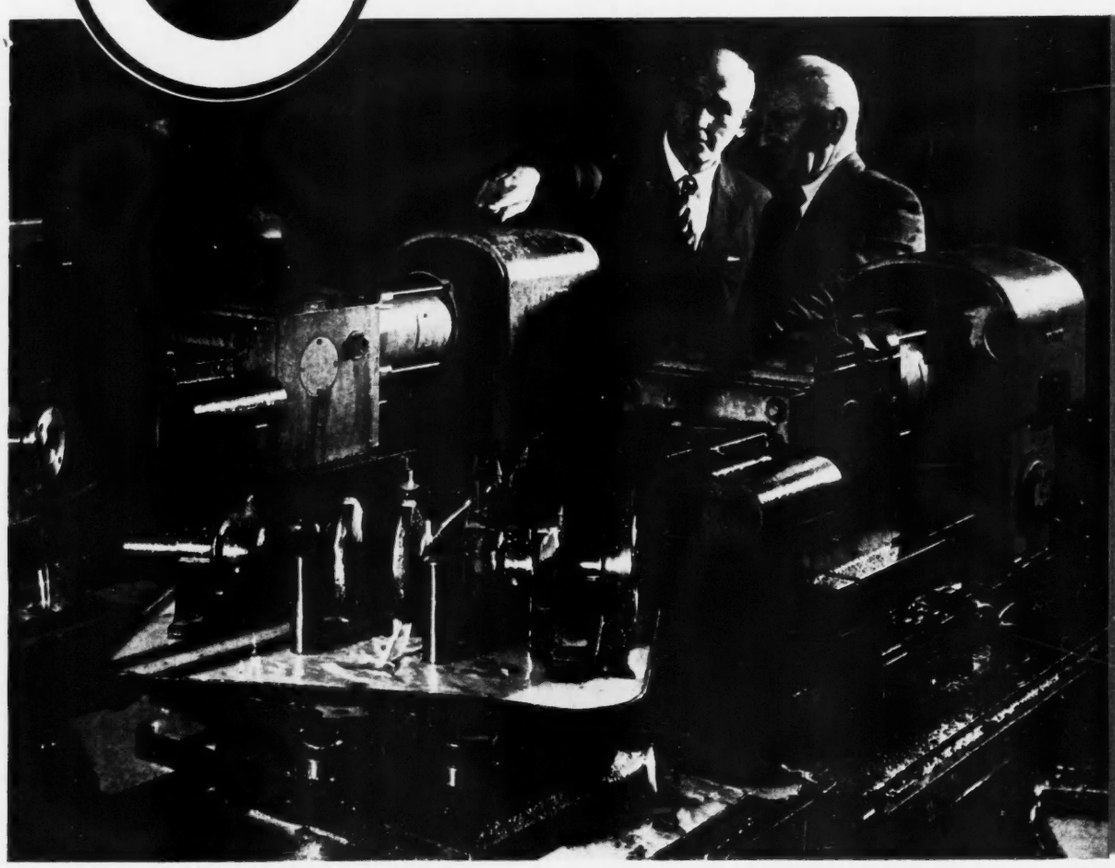

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To operate efficiently, even the simplest hydraulic system must be kept absolutely clean. This means that wear must be reduced, rust eliminated and gum and sludge deposits prevented.
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Which is why more and more British industries are turning to Regal Oils (R & O) for high quality performance and complete dependability.

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Regal Oils (R & O) contain powerful oxidation inhibitors which minimise the possibility of gum or sludge deposits and increase intervals between drain periods.

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Regal Oils (R & O) contain a rust inhibitor which 'plates out' on metal surfaces, forming a tenacious film that is impervious to rusting action of moisture and water. This eliminates the damage so often caused by rust.

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Regal Oils (R & O) are manufactured in different viscosity grades to meet every operating condition and give excellent performance at both high and low temperatures.
Regent Regal Oils (R & O) meet the requirements of the British Hydraulic Pump Manufacturers. The range comprises:
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THE ENGINEER

Sutcliffe

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200 LBS. P.S.I.

HIGH
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STEAM HOSE

PLUS POINTS

- *Natural rubber, heavy gauge, seamless tube.*
- *Manufactured in 60 ft. lengths.*
- *High tensile wire-braid reinforcement with special spiral asbestos cord which incorporates a static conducting wire.*
- *Light-weight yet of great strength.*
- *Neoprene cover, compounded to withstand extreme heat and abrasion.*

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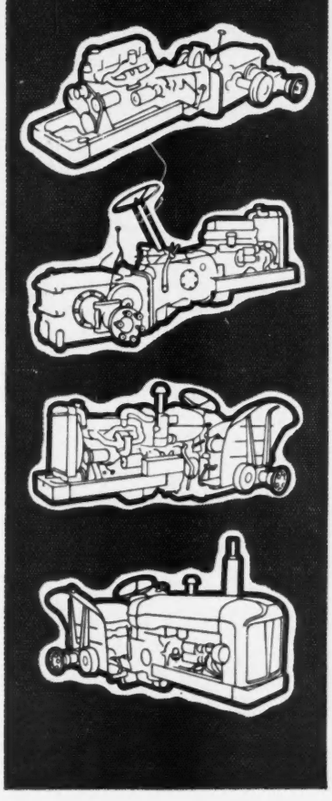

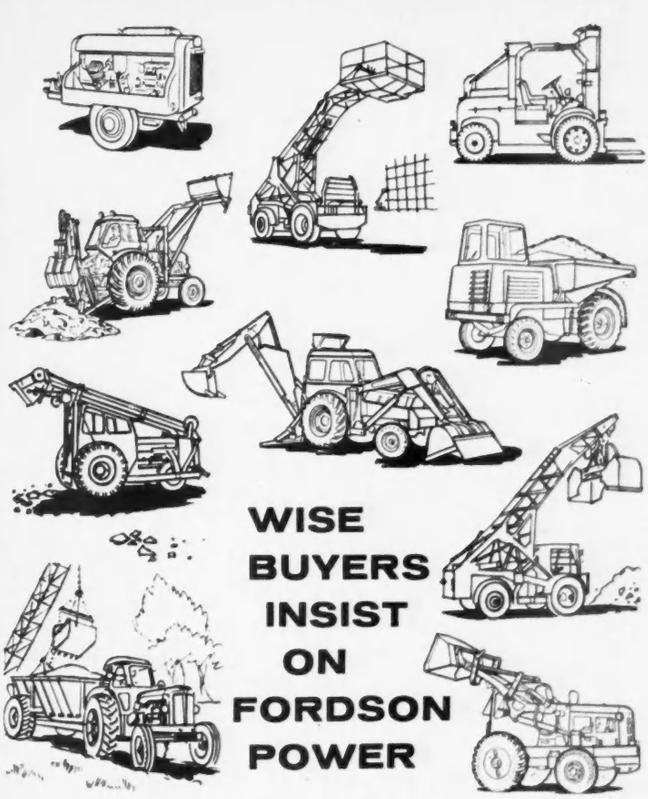

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WELLMAN

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now offer the

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Outputs have been greatly increased with an average of five thousand tons of steel per week.

This Furnace has now 90% availability together with lower than normal refractory costs.

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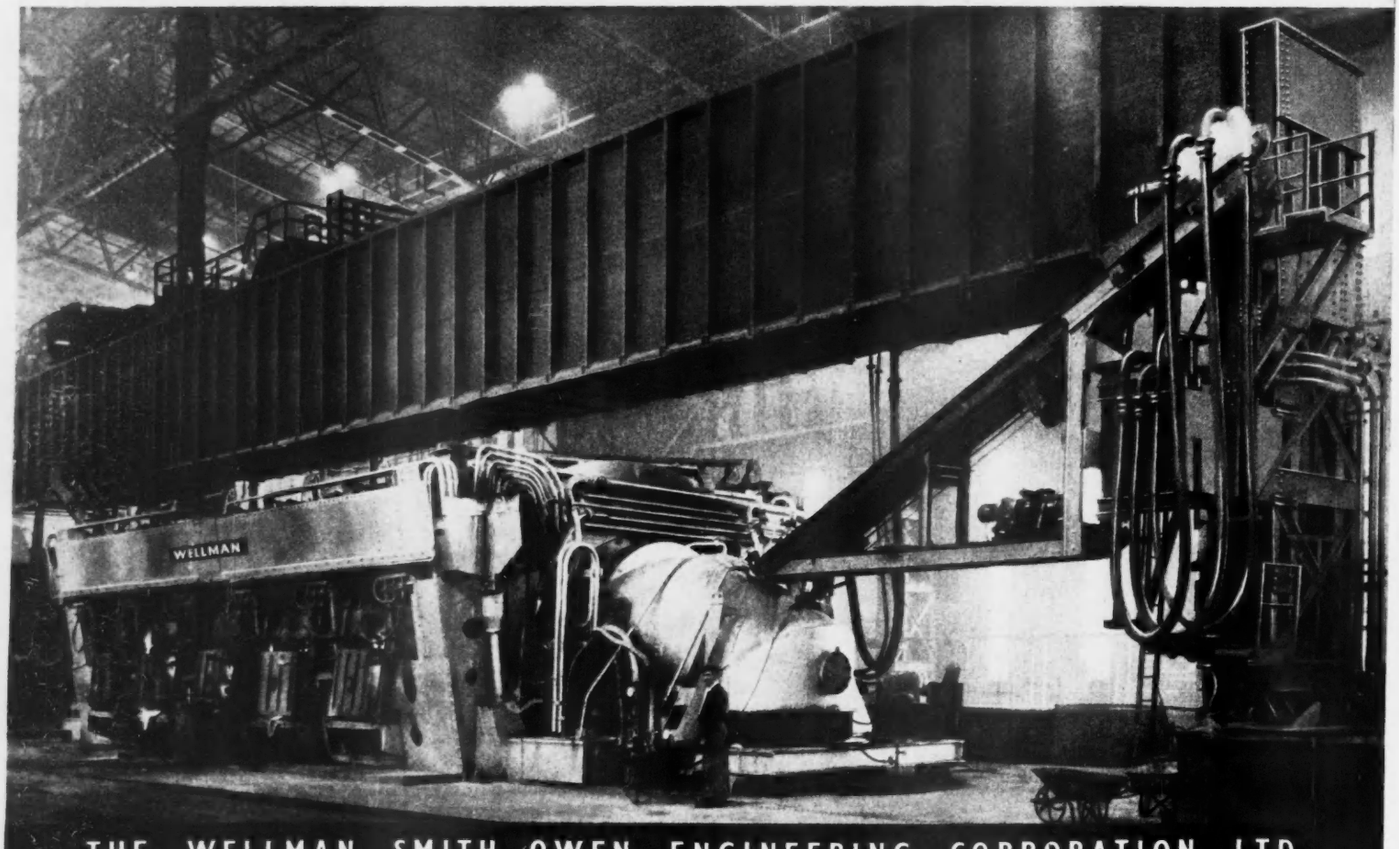

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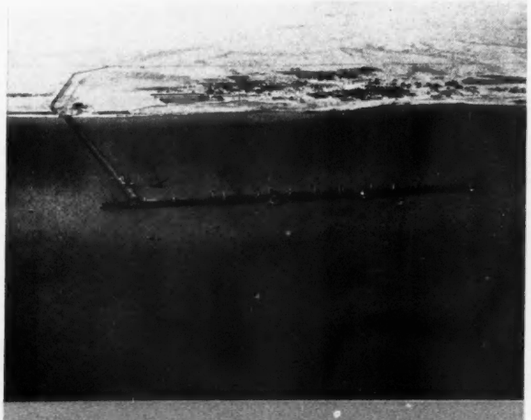

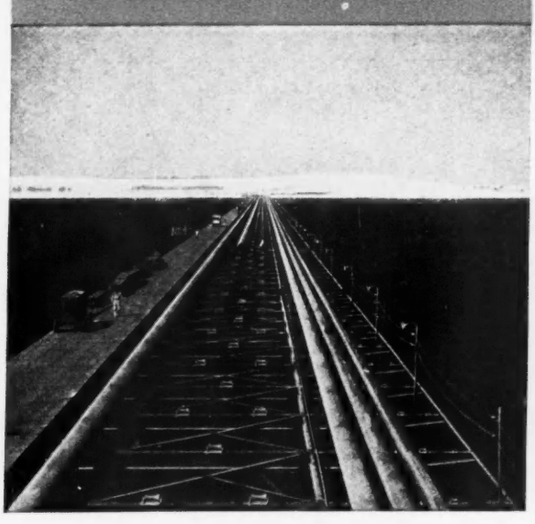

South Durham

at Mina al Ahmadi

For the construction of the Kuwait Oil Company's new North Pier at Mina al Ahmadi, Kuwait, and for extensions to its refinery, South Durham have been privileged to supply over 48,000 tons of steel made up as follows:

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"RENDHEX" FOUNDATION COLUMNS	**13,500**
PLAIN BROAD FLANGE BEAMS	**850**
TWIN BROAD FLANGE BEAMS	**2,030**
BROAD FLANGE BEAMS with plates welded to flanges	**2,640**
PIER DECKING	
BROAD FLANGE BEAMS (plain and plated)	**2,700**
EXTENSIONS TO REFINERY; NORTH PIER; TRANSIT AND GRAVITY LINES	
MILD STEEL PIPES from 18 inches to 40 inches diameter, automatically welded by the Submerged-Arc Process to A.P.I.5L Specification (approximately 100 miles)	**27,000**
Total tons	**48,720**

The pier is carried throughout its length on South Durham "Rendhex" Foundation Columns. Before shipment these columns were specially prepared at the South Durham Works where also all decking steelwork was prefabricated for welding on site. The total quantity of steel was shipped over a period of fifteen months. Another example of the way in which South Durham is "circling the globe with steel."

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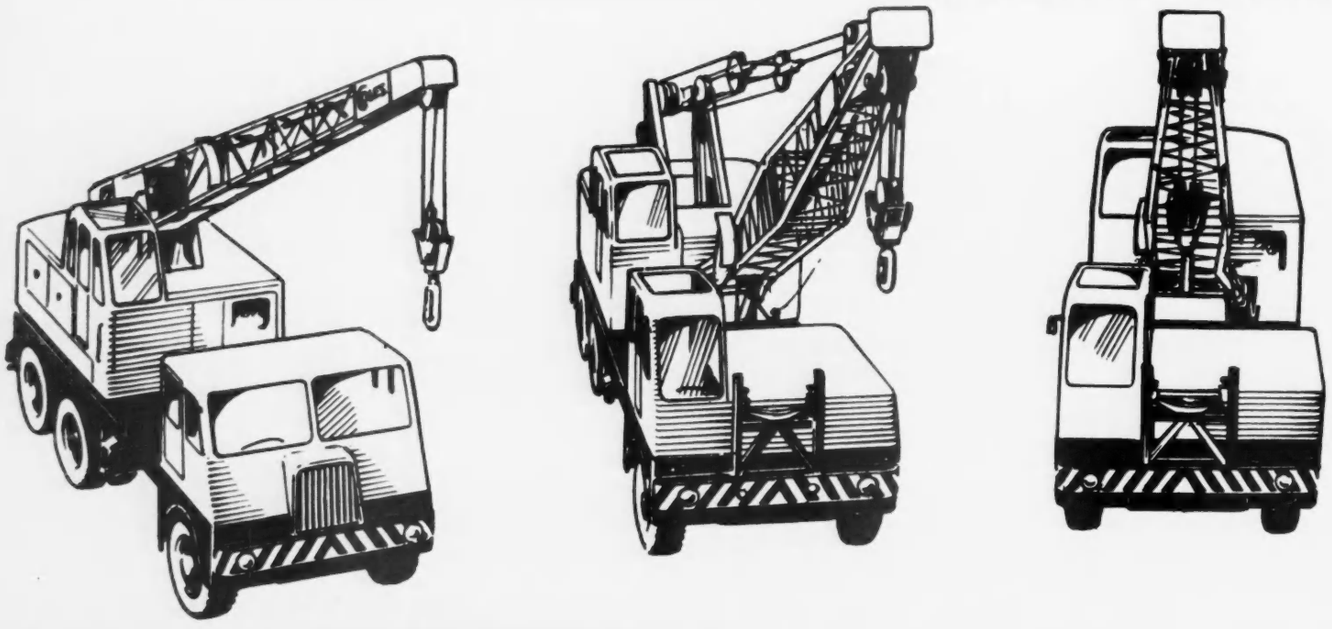
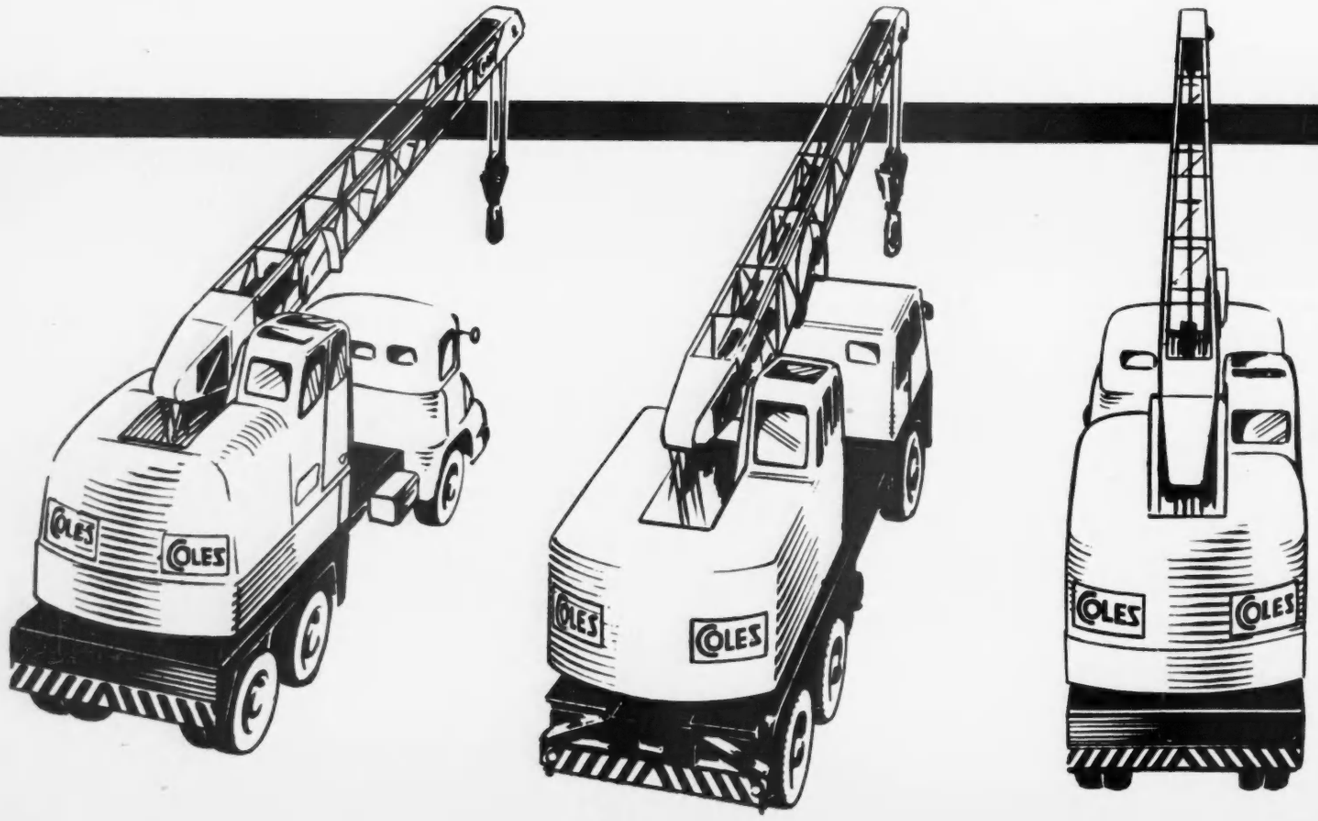


Wood, Pritchett & Partners Ltd., order another ten Coles Diesel-Electric Truck Mounted Cranes for their new depot



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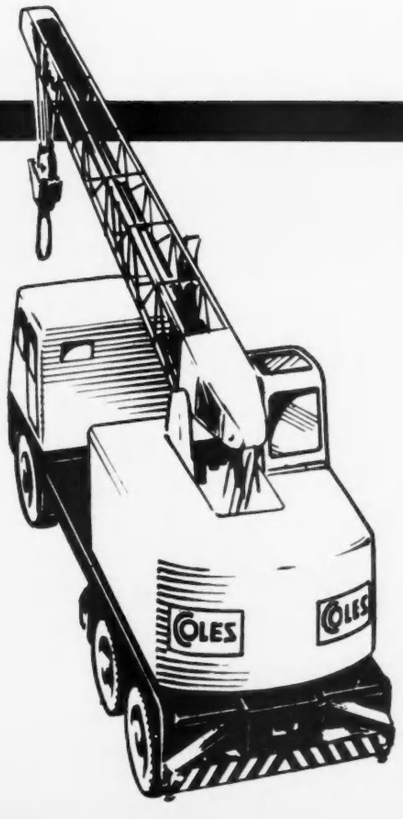

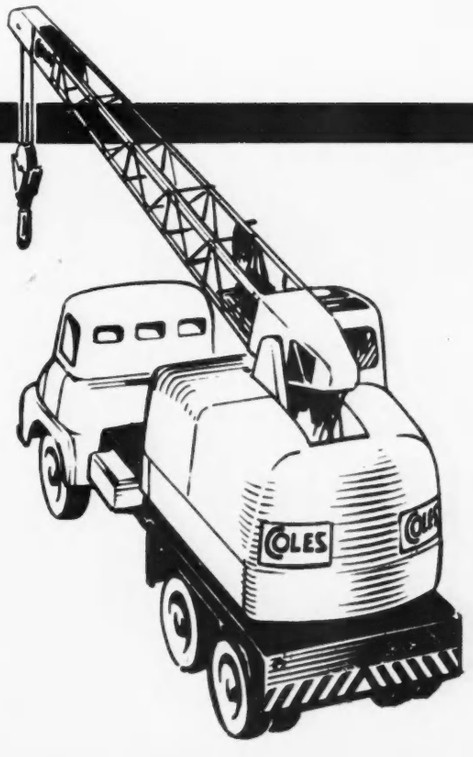

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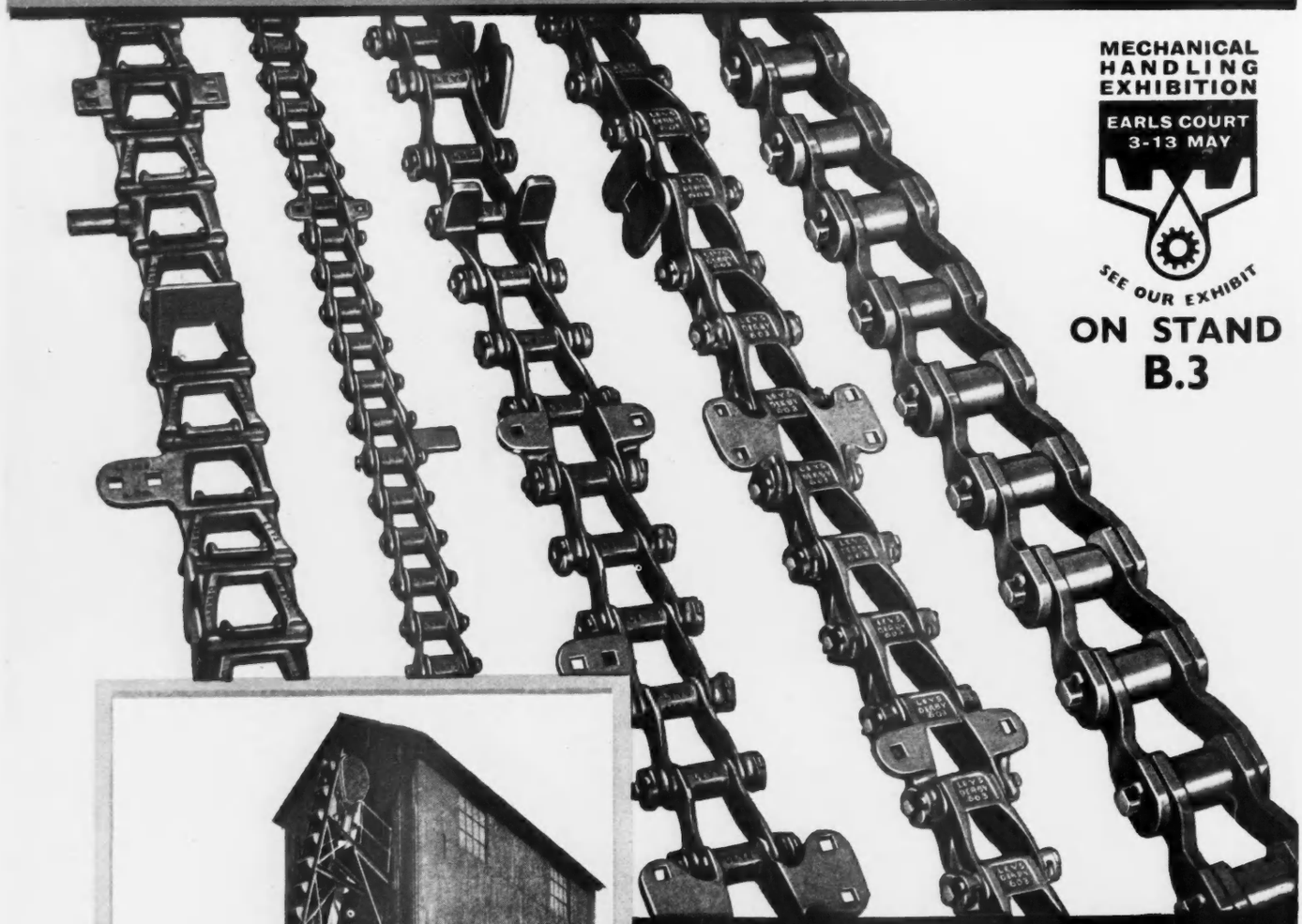

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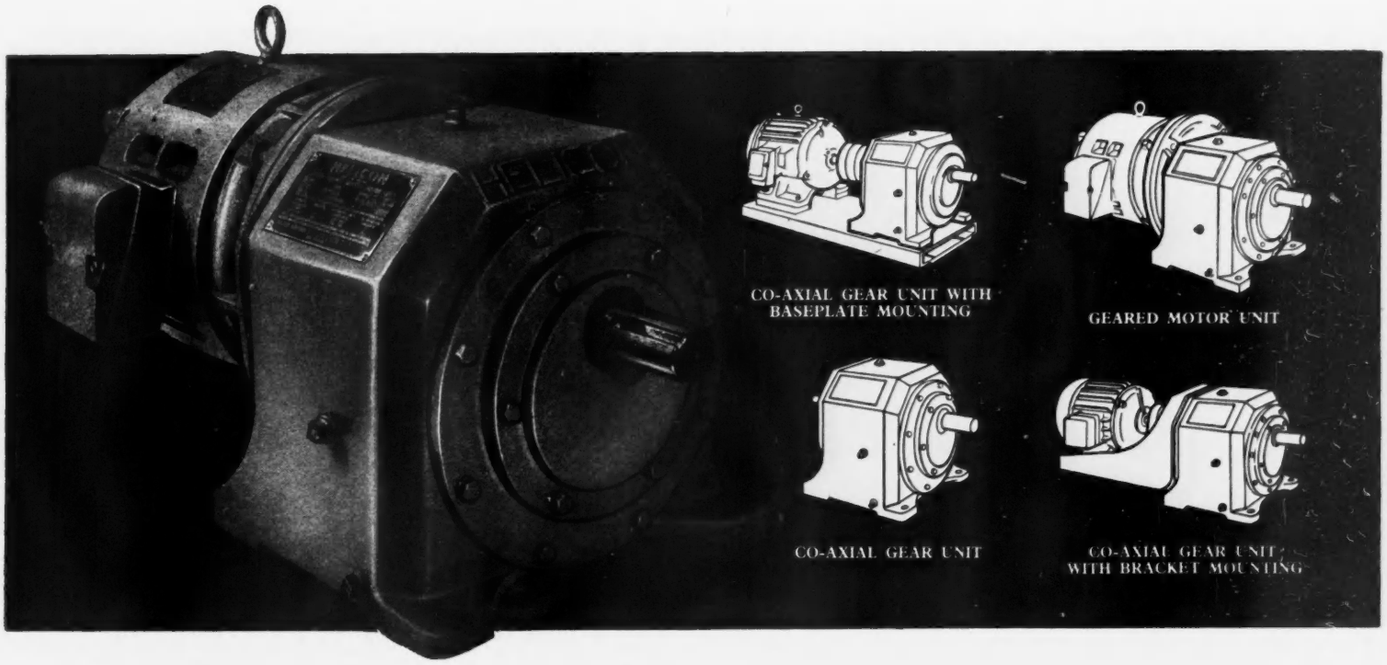
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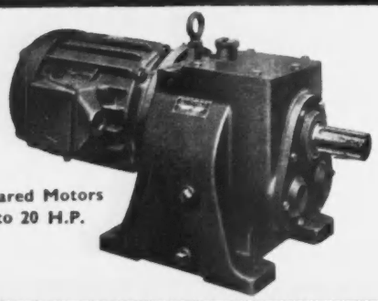

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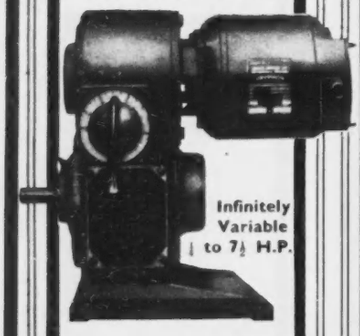

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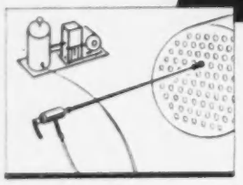

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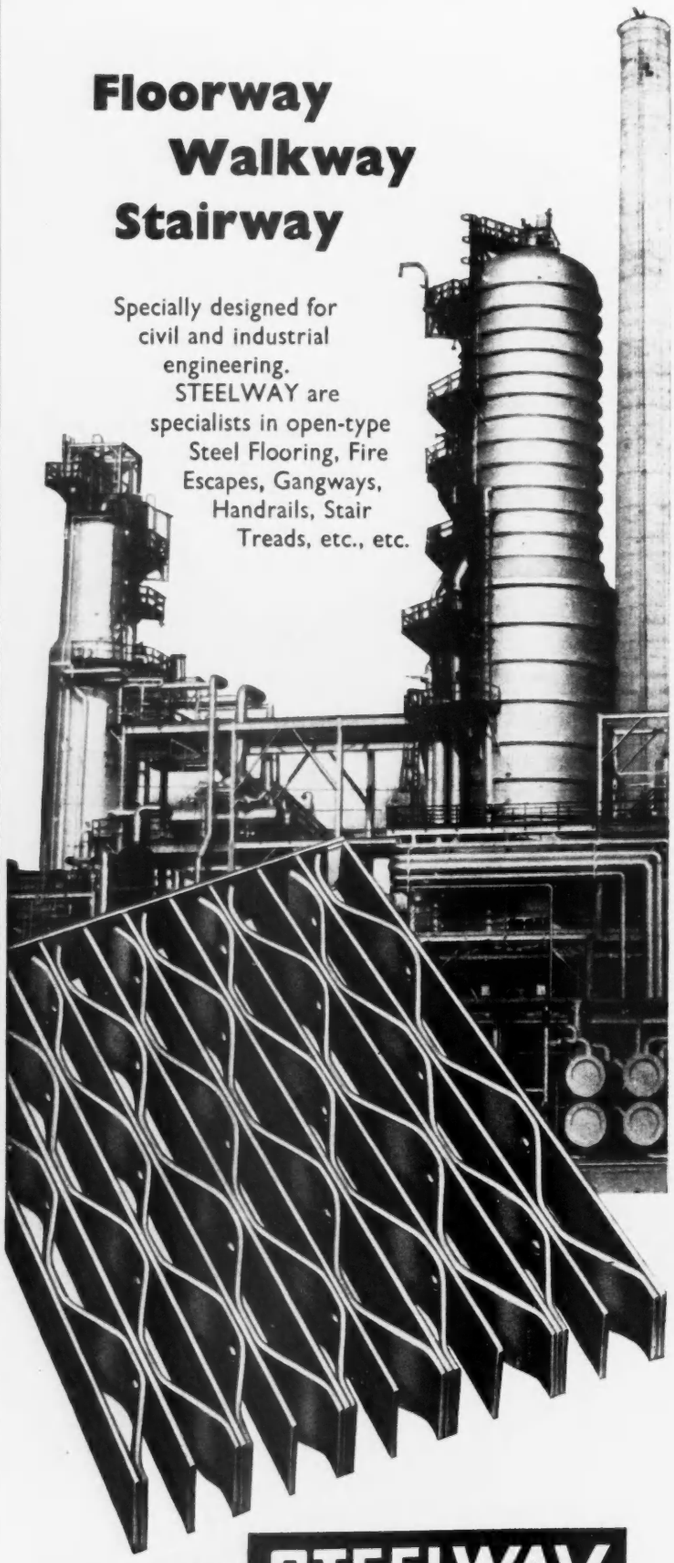

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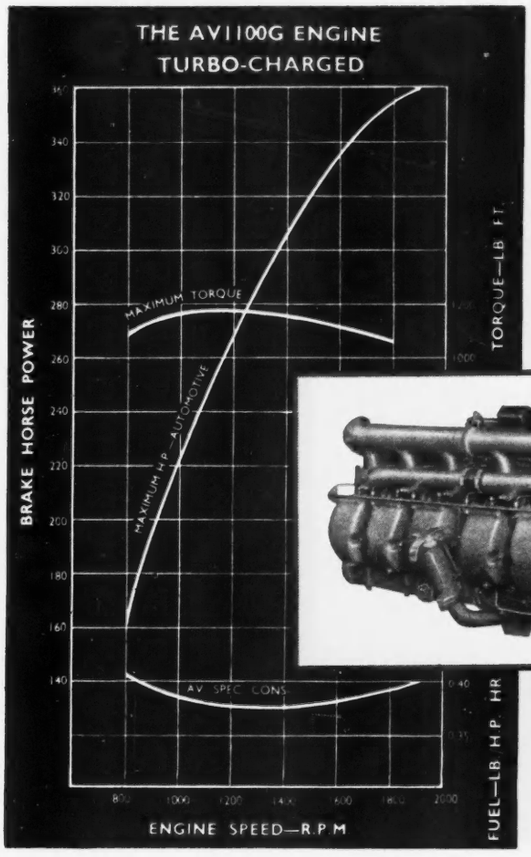

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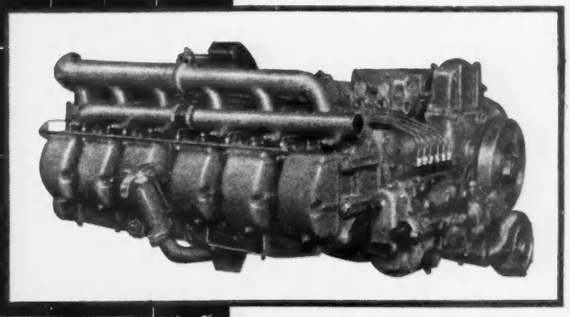

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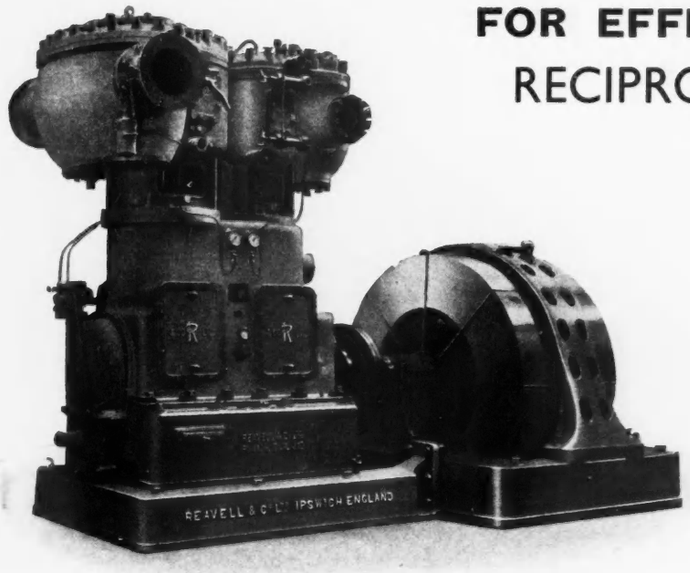

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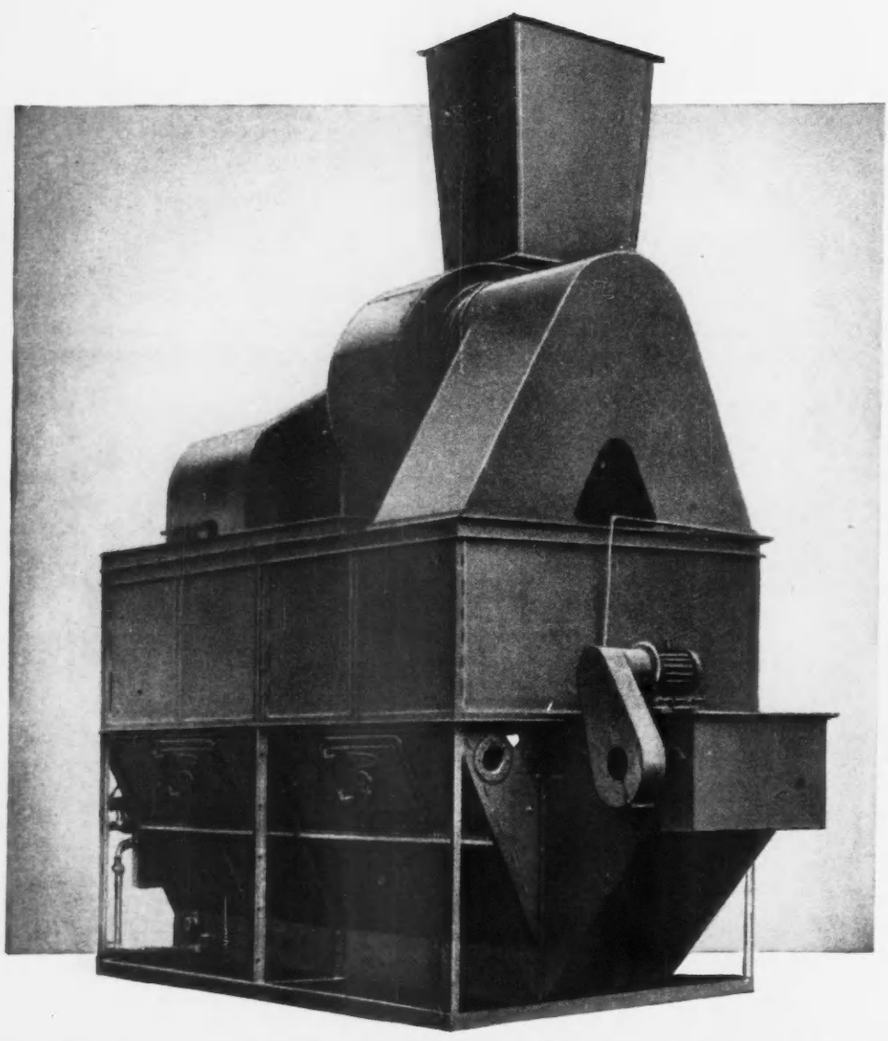

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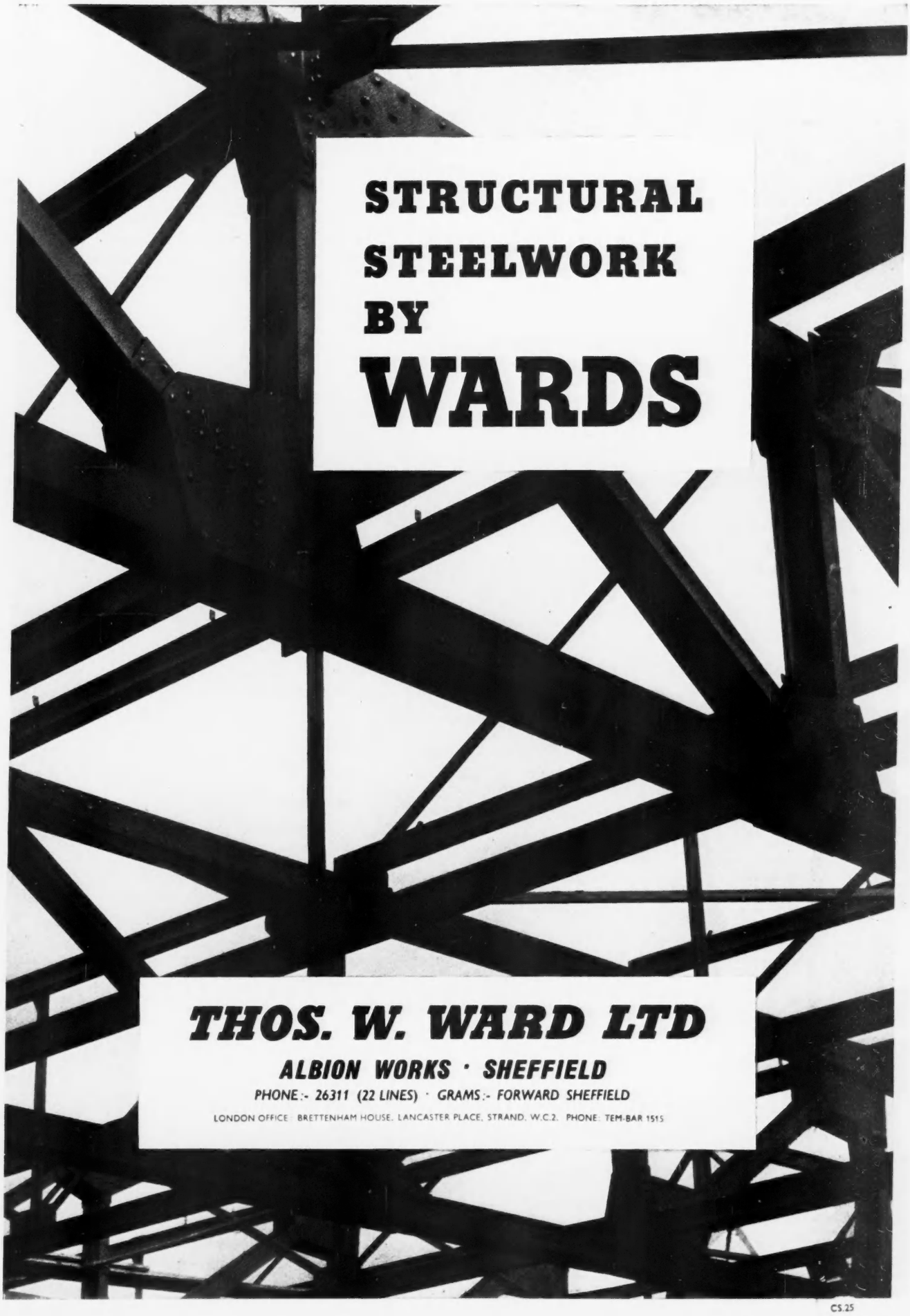

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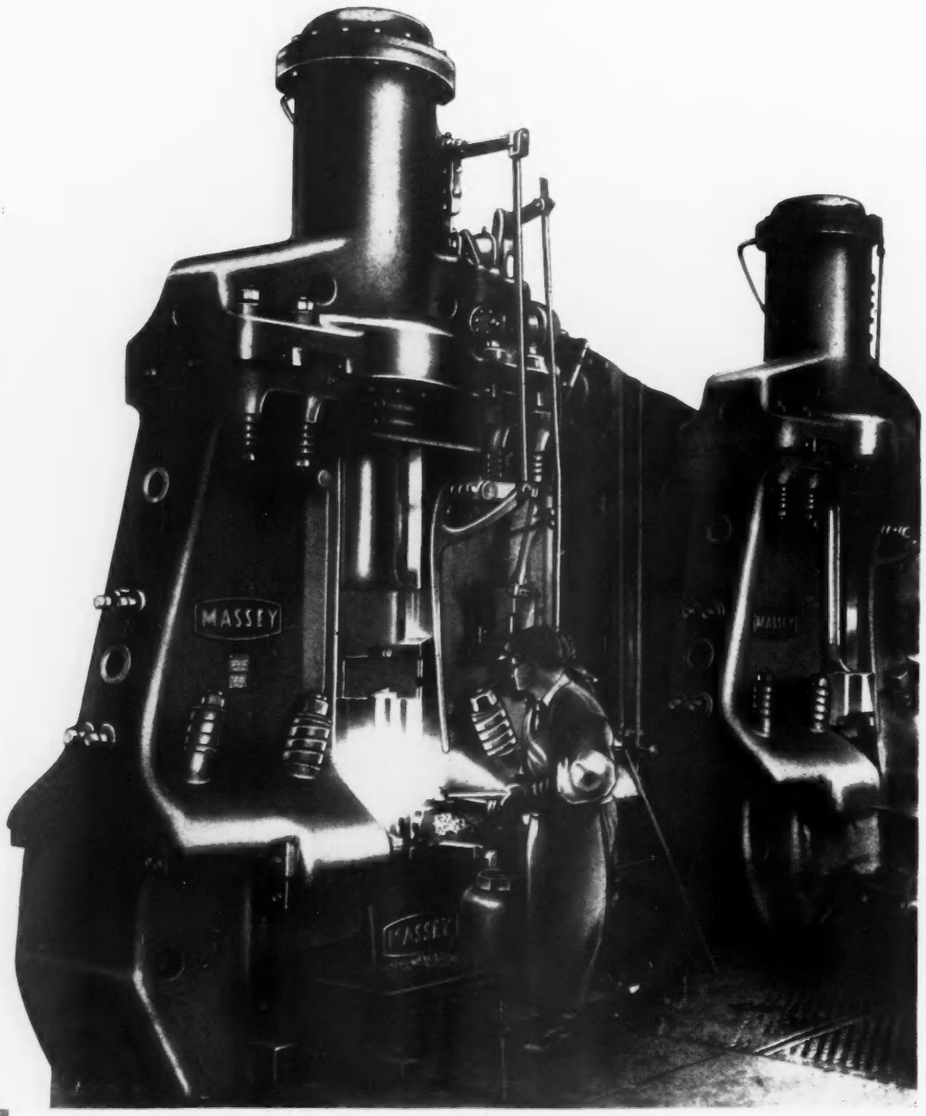

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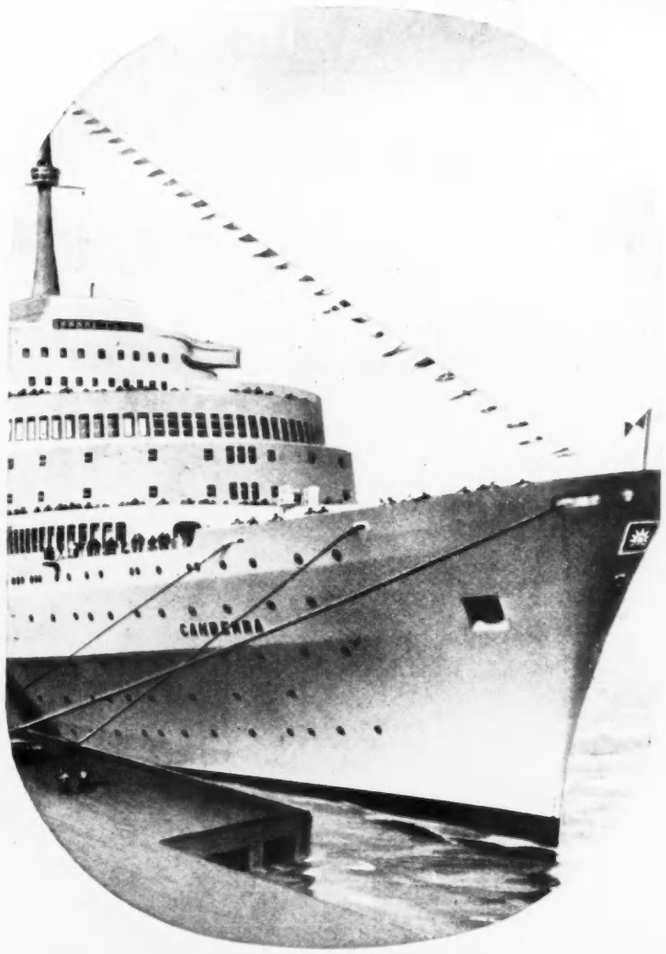

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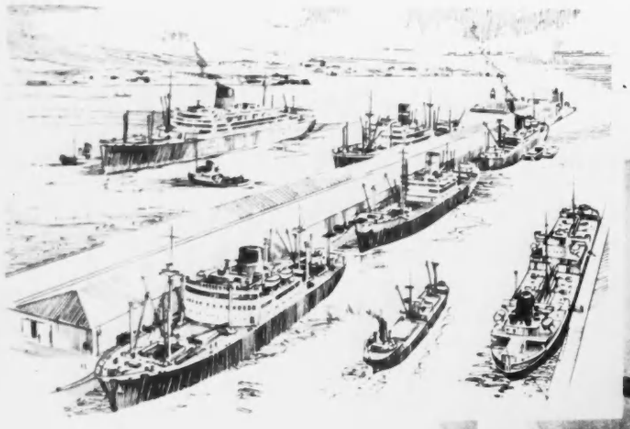

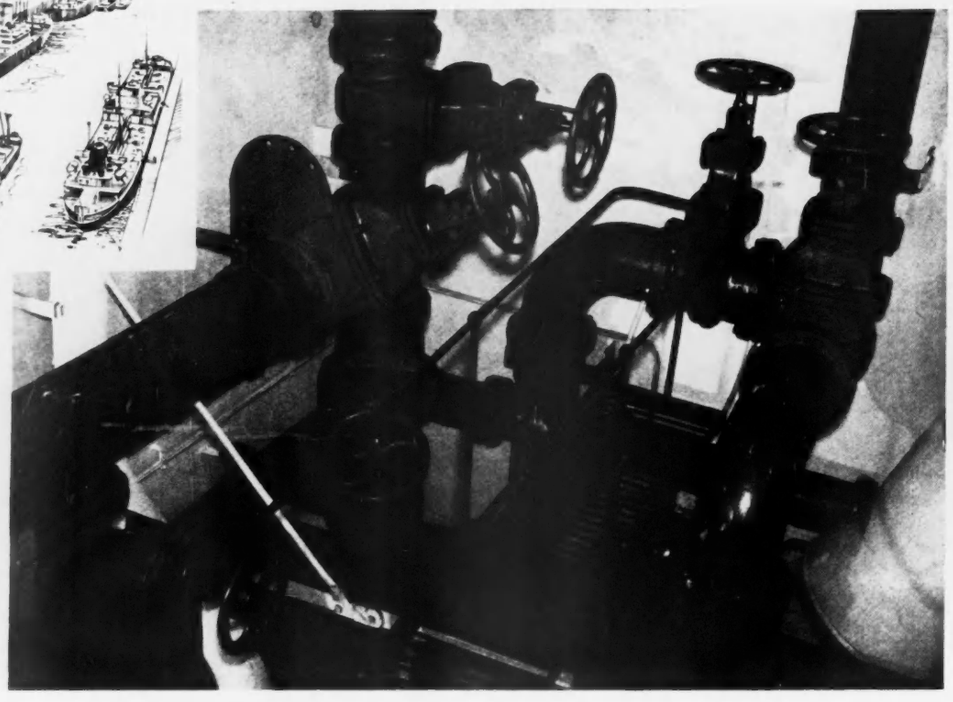

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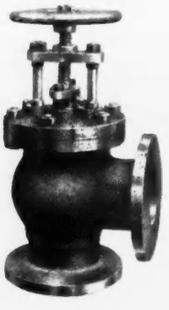

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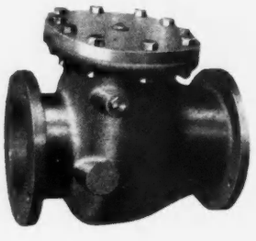

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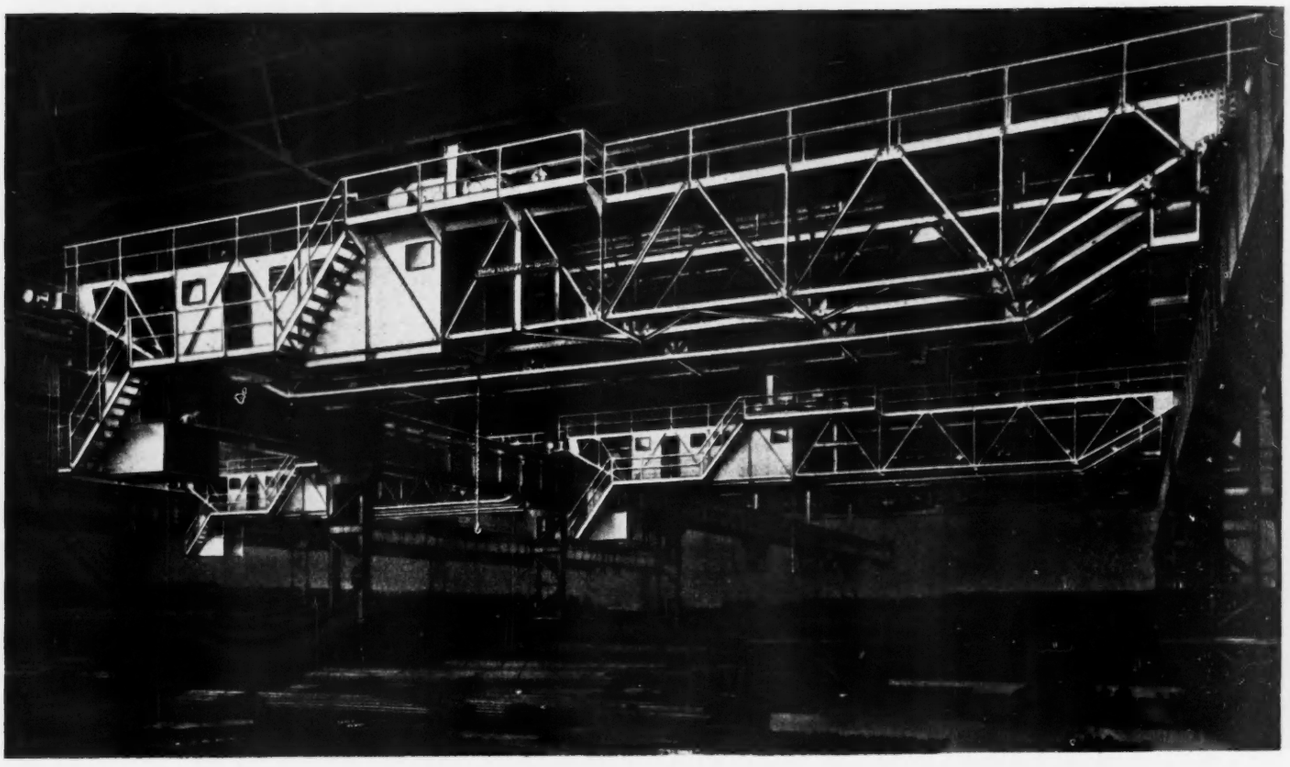

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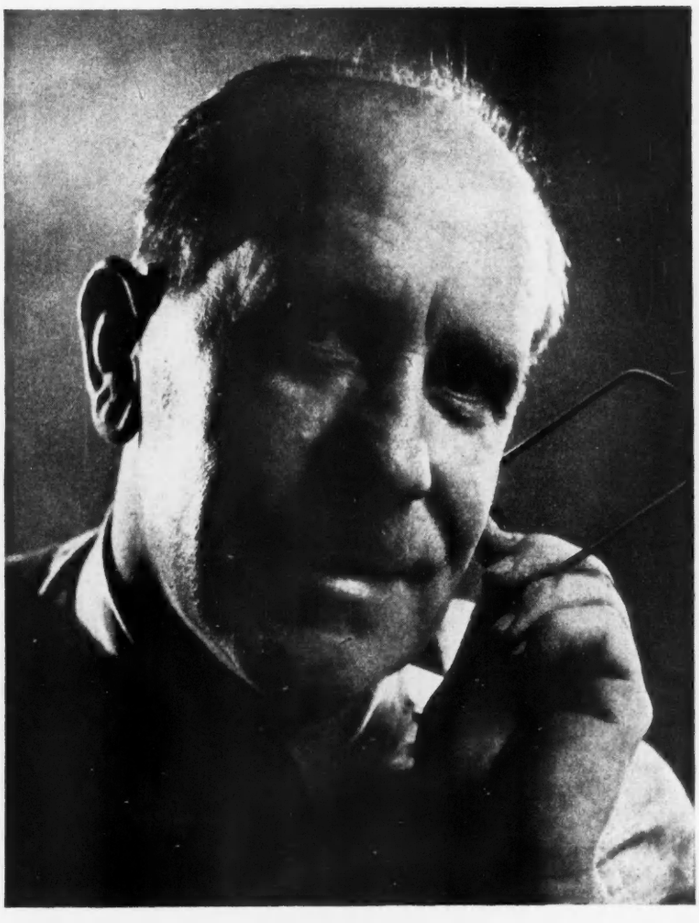

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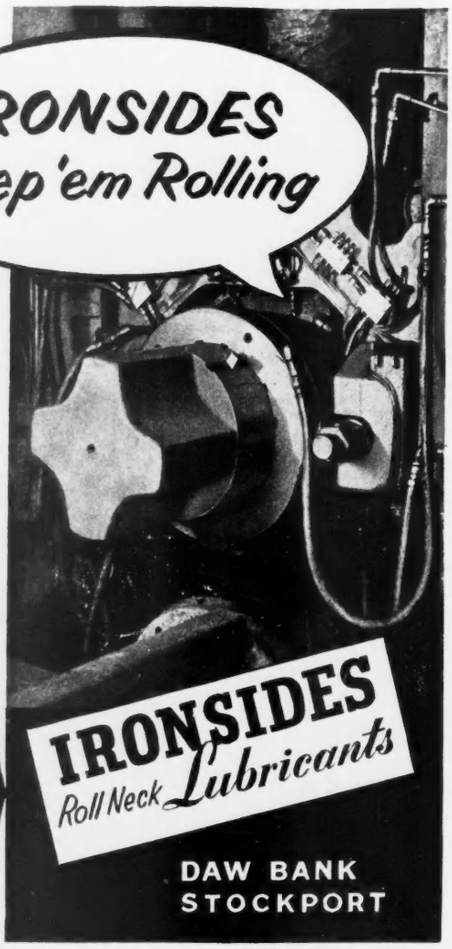

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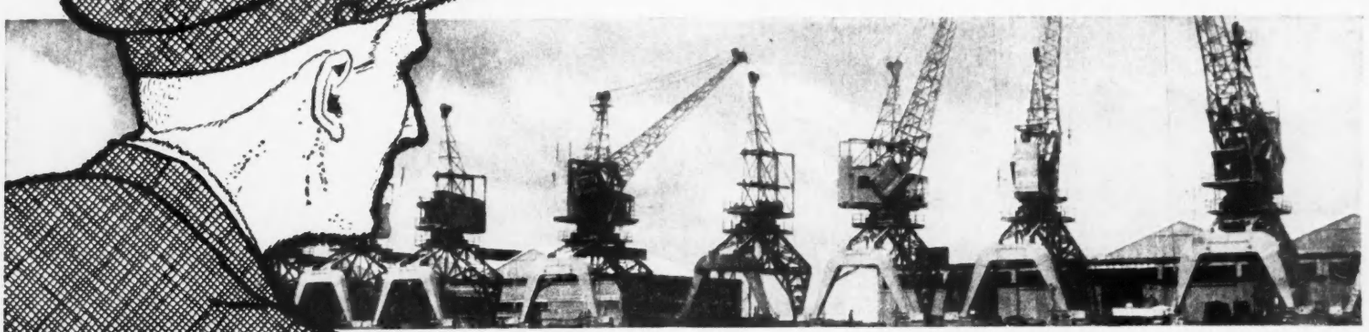

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THE ENGINEER

No. 5440 APRIL 29, 1960 VOL. 209

THE CHANNEL TUNNEL

The thoroughness with which the Channel Tunnel Study Group has carried out its investigations will be immediately apparent from the article on page 718 of this issue, in which certain of the technical considerations behind the alternative projects in the Group's report are explained. Broadly speaking, the Group has concluded that the tunnel is desirable and is economically sound ; a rail tunnel is preferred, but there appears to be no decisive advantage as between a deep tunnel driven through the chalk, or a " tube " tunnel sunk from the sea. It should, perhaps, be explained in amplification of the Group's preference for a rail tunnel, that it is proposed that road vehicles would be carried in special trains on to which cars would be driven over side-loading wagons at each end. These car-carrying trains would journey through the tunnel in thirty-five minutes (i.e. at an average speed of 60 m.p.h.) and would initially be single-decked. Ultimately, double-decked trains would carry 300 cars per train, it is envisaged. Lorries would be carried on special open wagons. Such a tunnel would have sufficient capacity for several decades it is considered.

Only three weeks ago we commented in these columns on the proposal for a cross-channel bridge. We pointed out then, how inspiring such a design was from the purely engineering point of view, and, of course, it must be said also that the tunnel schemes are of great technical interest, and are indeed equally inspiring to the engineer. The multiplicity of engineering firms which have been involved in the design studies, and the quality of the work which they have contributed, shows what a stimulating effect a project such as this one can have on technical thought. The Group's report, however, goes further than this, and covers all aspects of the scheme, including the financial and legal ones. With the more precise economic evaluations which are now given in the report, it appears that a bridge is ruled out by its higher first cost, but the economics of a rail tunnel are more favourable than we gave reason to believe in our earlier " leader," and the report modestly states that " the revenue from operating the tunnel would suffice to give a satisfactory return on capital invested." Given certain safeguards, private financing is favoured.

In contemplating a project costing over £100 million, however, even though as engineers it excites us considerably, there still remains the larger question of whether there is not a choice in the number and size of projects of this kind which can be undertaken, and if so whether other projects are not more worthy of priority. As we have pointed out already the outstanding case is that of road construction. If one can journey across the channel in thirty-five minutes, what use is it if one still takes an hour and a half to drive across London ? From the centre of London in the rush hour, for example, to the start of the M.1 takes much longer than thirty-five minutes ! If projects in other fields, and notably in the construction of roads can go ahead at a satisfactory rate, then let us have the tunnel, too ; but if there must be a choice—as seems to be the case—the tunnel should be deferred for a decade or so. By then, too, " Hovercraft " development may have provided a much cheaper alternative.

RING MOTORWAY FOR LONDON

The British Road Federation has put forward a suggestion that a " ring " motorway encircling London from 2 to 4 miles from the centre could be built almost entirely above or alongside existing railways. By the choice of such a route the greatest difficulties of an urban motor road project—land acquisition, demolition of property, and severance of communications—are effectively minimised. It is interesting to consider this suggestion in the light of the comments made above on the Channel Tunnel project. The Federation's ring motorway would be 25 miles long and would cost £83,500,000 (including £21,000,000 for a new tunnel at Rotherhithe), it is estimated. Radial roads in the L.C.C. area would cost a further £9,000,000. The two projects are thus of comparable mileage and cost ; which would bring the greater benefit to the community, if a choice had to be made between them ?

In putting forward the Federation's case for the ring motorway proposal, Lord Derwent said that in the Federation's view, highway improvements in the revised development plan for London were totally inadequate. " We feel," he went on, " that every aspect of the plan is so dependent upon proper provision for traffic that we have entered a formal objection against the plan as a whole because, in our view, no part of it can be in the public interest while the fundamental of road communications is dealt with so inadequately." These words indeed coincide closely with the opinions already expressed in this journal on the L.C.C.'s development plan.

The advantages of the Federation's ring road do indeed appear to be substantial. The need for a London ring road has been stressed by many planning authorities, its function being to cross-connect the various radial links joining with routes such as the M.1. About 5 miles of the proposed 25 mile route would need an " alternative " route, i.e. away from railway land. The motorway would run from a new bridge over the Thames at Fulham to Walham Green, Kensington, Westbourne Park, Kilburn, South Hampstead, Camden Town, Islington, Hackney, Poplar, Stepney, a new Thames tunnel at Rotherhithe, Bermondsey, Camberwell, Denmark Hill, Brixton and Battersea. The cost compares with an estimate of £150 million made for the 11 mile long " A " ring. The Federation suggests that this route should form an early stage in a fifteen year programme of road developments in London, which should be based on integrating this ring road into the London Road Committee's proposals. An annual expenditure of £18,000,000 to £20,000,000 is suggested over the fifteen years.

PRODUCTION AS A CAREER

It is becoming habitual for the Institution of Mechanical Engineers to make a resounding success of the Leonardo da Vinci Lectures for schoolboys and schoolgirls, which are presented each Eastertide at headquarters. The fifth such lectures were delivered on Thursday of last week, April 21, and dealt with "The Manufacture of Gas Turbines—Applied Science in Practice." It was the first occasion on which the actual production side of the work of engineers has received attention. As has become usual a team of speakers was involved in presenting the subject. Mr. Feilden, managing director of Hawker Siddeley Brush Turbines, Ltd., and a director of Hawker Siddeley Industries, Ltd., who organised the affair, took the chair and delivered an introductory address; then Mr. Frank Nixon, chief quality engineer of the aero division of Rolls-Royce, Ltd., got down to a short description of a gas turbine engine and went on to refer to the conversion of ores into metals; the fabrication of the latter into bars, sheets, &c.; its casting and forging; its machining; the assembly of manufactured parts into machines; and the organisation of production. Lastly, Mr. R. R. Whyte, who is now in charge of four factories of the Associated Electrical Industries turbine generator division spoke about craftsmanship, the special technical problems of the gas turbine, how certain manufacturing problems are overcome and the contributions to the solution of production problems being made by research.

All three speakers had certain remarks to make which were of interest to the adults present besides the children. Mr. Feilden, for example, stressed that there is a need to attract a greater proportion of men with first-class brains coming out of universities and technological colleges into the production side, which offers problems needing solution every bit as important as those encountered in more formal research and especially challenging to an inventive mind. Mr. Nixon made the point that because the production engineer has to exercise a great deal of technical ingenuity in solving his problems he is not infrequently achieving results by methods that are ahead of full scientific knowledge. Mr. Whyte made the interesting suggestion that graduates planning to take administrative posts should first of all be given responsible work on the production side but without executive authority to order anyone about. In those conditions, to be successful in getting their ideas accepted and their proposals tried out, they have to develop not only technical ability but methods of persuasion. Their success or otherwise under these circumstances gives, Mr. Whyte thinks, a good indication of the likelihood of their success in handling men and thus of their probable ability in managerial posts.

OLDER WORKERS

Among its many other activities, the Department of Scientific and Industrial Research is disseminating the results of recent research into the social, economic and technical problems of industrial progress. It does this by a series of pamphlets presenting briefly and simply the material prepared by experts who are investigating particular problems. The latest pamphlet in this series reviews research carried out concerning older workers in industry. There is no doubt that it is in the social and economic interests of employers and society as a whole to make the fullest use possible of the experience and capabilities of older workers in a period of rapid technological development and industrial expansion. But definition of "older worker" is not altogether easy. It may still be fairly reasonable to claim that "a man is as old as he's feeling" but when it comes to research of the kind surveyed in the D.S.I.R. pamphlet it is necessary to be rather more arbitrary! In this context, therefore, "older" includes anyone aged forty and over. This age appears to have been chosen because research has shown that the effects of some mental and physical changes on performance in industry begin to become important by the forties. Furthermore, 50 per cent or so of the total number of men in employment in this country are over forty. Recent researches have revealed that where a job demands knowledge, accuracy and stability, older workers compare favourably with younger men. The most serious difficulty for older people, however, appears to arise from demands for speed; this difficulty being most severe when there is a rigid requirement for workers to keep pace with fast-moving machinery. A survey has shown that the numbers of both men and women engaged in work of this kind remain high until the middle forties but tail off quickly from the early fifties. This slowing down, it is suggested, is not so much owing to loss of speed in the actual making of muscular movements as to slowness of making decisions and of relating what is seen to what has to be done. Another interesting factor deduced from the investigations which have been made is that, provided they are not debarred from heavy physical work on medical grounds, older people find its demands less exacting than those made by lighter work involving pressure for speed.

Undoubtedly, as the pamphlet urges, there is scope for continued investigation of this interesting and important subject of older workers in industry. The fuller mechanisation not only of manufacturing processes but of all kinds of other tasks has by no means reached its peak. In the planning of such mechanisation, the number of matters which engineers must take into account is increasing. A study of this latest D.S.I.R. pamphlet makes us feel that they include, for example, matching the "recklessness" of youth with the "steadiness" of age. Another question which does not yet appear to have been satisfactorily answered is whether the increased expectation of life implies that people retain their youthful energy and alertness longer or develop their ageing tendencies earlier? We agree with the author of the pamphlet that the need for more facts remains, for, so far, the information has been concentrated on what jobs are unsuitable for older workers rather than pointing out those which they can best do.

DETERGENT TROUBLES

One of the troubles with which sewage works engineers have to contend with is that of foam production in the treatment of sewage as a consequence of the use of detergents within industry and in the home. The trouble is persistent in that the effluent from a works upon discharge to a river may give rise to foaming below weirs, &c., with a bad effect upon amenity and, if the river is used by barge traffic or for boating, some risk to life in that it would be difficult to aid any non-swimmer who happened to fall into a foam-covered stream. Appreciation of these and other factors led to the setting-up in January, 1957, of a "Standing Technical Committee on Synthetic Detergents." That body has just issued its third report.

There has, it appears, been little increase in the use of powdered detergents in the last two years, but the domestic

use of liquid detergents has increased and continues to increase. In that respect, therefore, the situation is deteriorating. However, it also appears that, at least to date, liquid detergents contain quantities of material resistant to oxidation at the sewage works which are small compared with the amount used annually in the powdered form, so that there has been no appreciable effect upon the overall position. In the meanwhile, hope has arisen that the situation can be fairly simply eased. The trouble is largely to be traced, as was pointed out in a previous report of the committee, to the presence in certain detergent mixtures of alkyl benzene sulphonates which are not amenable to biological decomposition. But it has also been discovered that such sulphonates are more readily decomposed if the alkyl part of the molecule is of a simple straight chain configuration ; and the detergent characteristics are not affected thereby. Manufacturers were therefore asked to produce mixtures containing such sulphonates ; and after pilot-scale experiments conducted by the Water Pollution Research Laboratory had shown that 94 per cent of this new material was destroyed by activated sludge or biological filter treatment, as compared with only 68 per cent of the old material, a full-scale experiment was attempted at Luton and Harpenden on the upper reaches of the River Lea. It is with that experiment that the present report especially deals. Manufacturers co-operated and agreed to supply only detergents with the new material within the areas served by the relevant sewage works ; tests were carried out upon effluents ; and observations were made of the degree of foaming at a certain point on the River Lea known to be badly affected. For certain reasons connected with an unexpected difficulty of ensuring that only a small proportion of detergents used in the area should contain the old material (some 30 per cent did not) and certain difficulties encountered in analysing samples, the experiment proved somewhat inconclusive. But tentatively a conclusion is drawn that while the new material is not completely removed during sewage treatment, its substitution for the material now in general use would substantially diminish the troubles associated with synthetic detergents. Manufacturers, however, may have regarded the results of the experiments as more conclusive than does the committee. That seems a fair inference to draw from the fact that all of them, having co-operated fruitfully with the committee, have now extended the distribution areas of the new material in an attempt to reduce the entry of old material into the experimental region. It may be even more significant that one of them (perhaps already convinced) has extended the cover to a wide area in the South of England.

INDUSTRIAL VALUE OF D.S.I.R. RESEARCH

In this issue we begin to publish the first of a number of articles—to be published from time to time—which will study the industrial value of D.S.I.R. research. Our purpose is to discover how much use is being made of the work done at D.S.I.R. laboratories. Our method is to visit a laboratory and to ask its director to bring to our attention recently published papers describing its researches within some more or less limited field. We then summarise the papers concerned—giving the full references so that the papers themselves can be studied if readers wish to take that amount of trouble—ask for and receive the concurrence of the laboratory that the summaries do fairly represent the contents of the papers and send out proofs of this material to a number of firms which, we think, may have made use of the information. We follow up in person, asking for comments and, more especially, for particulars of any real hardware produced by the firm, the design of which has been influenced directly or indirectly by the work of the laboratory and for information about any work the firm may have carried out itself in the same field, and so forth. The resultant report, which has to be approved by the firm before it gets printed, represents as accurately as we can manage what the representatives of the firm said to us. We ourselves express no opinions. Readers, we think, will prefer to draw their own conclusions upon the basis of what we print. The first article of this kind, only about half of which appears in this issue, is concerned with certain hydraulic subjects, investigated at the National Engineering Laboratory at East Kilbride, especially interesting to pump manufacturers, makers of valves and makers and users of oil hydraulic machinery. It has proved not at all easy for some firms to pinpoint what use has been made of the laboratory's work. Nevertheless, the comments made support the view that these particular researches have proved really valuable.

Possibly a number of firms, upon reading the present article, may ask why THE ENGINEER picked upon their competitors rather than themselves for interview. The answer, of course, is that it would have been quite impracticable for us to have visited and interviewed all the very many firms which might have proved interested enough to comment ; for within the subject of the particular article, there must be hundreds, if not indeed, thousands of them ! We should like to emphasise, however, that, provided there is no substantial repetition of anything already said or of any point already made, we shall welcome contributions from such firms in the form of letters to the Editor.

The Engineer—100 Years Ago (APRIL 27, 1860)

"ENGINEERING EMPLOYMENT"

"When Telford had finished his splendid system of highways and canals, it might have been supposed that no more such extensive works remained to be constructed. In 1848, too, it was thought that the country had been over-run with railways, and that very few, if any more, would be undertaken for many years. . . . In our extension of the means of artificial communication, a great share of the wonderful results which have been attained is due to the improvements which have been made upon earlier practice. Whenever better modes of construction have been discovered, and the same results obtained with less money, the engineer has found himself in fresh request. And so it is now : every step made in simplifying and cheapening engineering works, whilst retaining their necessary durability and capacity, increases, by cheapening the supply, the demand for such works, and thus engineers have the power, to a great extent, in their own hands of multiplying at will the sources of their own employment. Fresh talent, new applications, and better processes must always be in request. The whole spirit of commerce, upon the progress of which all engineering employment depends, is opposed to repetition and routine as long as any fresh profit can be extracted from alteration and improvements.

"Notwithstanding the opposition of certain conservative members, the profession is undoubtedly keeping pace with its opportunities, and the keenest competition is manifested in many quarters in the testing and adoption of improvements. More and more liberal ideas are continually gaining momentum, and the monuments of the old school of practice stand very little chance of being copied, unless their merit is apparent under the closest comparison with the latest efforts in the same line."

Industrial Value of D.S.I.R. Research—No. I

PART I

FOREWORD: Engineering is essentially a practical business in that the products of the engineering industry are real things useful in one way or another to mankind. Yet, by contrast, the products of engineering research (as opposed in the present context to development) are usually ideas expressible only on paper in words, in mathematical equations, by drawings, or by diagrams. Such products can attain a real value only if they are applied by designers, manufacturers, or users of engineering devices. To what extent, then, is the work done at research laboratories in fact applied by more practical engineers? It is the object of this series of articles to throw some light on that question. The inquiry is confined to D.S.I.R. establishments; and the method is to select certain papers published by such establishments and to ask a number of firms whether they have made use of the information and, if so, to what extent design, or manufacture, has been altered thereby.

INQUIRY CONFINED TO D.S.I.R. ESTABLISHMENTS

THE object of this series of articles, as defined in the foreword, is to examine to what extent the ideas expressed on paper, in words, in mathematics, in drawings, and in diagrams by research workers in published papers are actually used by more practical engineers in designing, manufacturing, or using real hardware. If that is to be the object of the inquiry, it may well be asked, why is it to be confined solely to D.S.I.R. establishments? For many other bodies carry out researches. The answer, of course, is that the task would be far beyond our powers were it not possible to simplify it somewhat. The simplification arises because it is possible to make the assumptions listed below about the value of certain research bodies; though we hasten to add that we realise the validity of the assumptions is by no means unchallengeable.

(1) No firm is likely to continue to operate its own research laboratories unless its directors believe value for money is gained from the work. It may, of course, be argued that it may be the fashion for firms to have research laboratories and that even hard-headed business executives may feel it necessary to conform for reasons of prestige. Even so, we cannot see those executives standing for very long for a department that shows little or nothing in return.

(2) No firm is likely to contribute regularly towards the cost of running a research association unless it is reasonably confident of getting value for its money. Since most (if not all) research associations have had the experience, since the war, of continuously increasing industrial support it must be supposed that those bodies are doing at least enough good work to justify their existence.

(3) No individual research firm, doing sponsored research or living by granting licences for the use of its patented research discoveries, can possibly continue to exist unless it produces results of value.

(4) University research must be placed in a special category. Much of it approximates to research in pure science, that is, it is done in the pursuit of knowledge for its own sake and does not need to be justified by any use to which it can be put.

There remain only the research establishments that come directly under D.S.I.R. control and whose funds are wholly or very largely derived from the national exchequer. It is especially pertinent to make an assessment of their value. For the jobs of D.S.I.R. establishments are significantly different from those of any of the others we have mentioned. As a very broad generalisation (any engineer aware of their work could cite, offhand, examples to the contrary!) they are concerned with more fundamental work than the rest and with the study of phenomena of interest across whole wide fields of industrial work (The National Engineering Laboratory, for instance, has made notable contributions to the study of lubrication and friction; and the National Physical Laboratory constantly improves the accuracy of standards of measurements); or they are concerned with relatively specialised fields (for example, the Water Pollution Laboratory); or they are there to undertake the early stages of works into projects that seem promising but which are too uncertain of a return for any individual firm to undertake (for example, Warren Springs Laboratory). They are open to the accusation that the work they are doing is too " high-faluting " and that it has no application in the real practical engineering world. The object of this series of articles is not to prove one thing or another nor to preach the value of D.S.I.R. establishments. It is to try to find out how much use is actually made of D.S.I.R. research results; to gather facts, not to draw conclusions from them.

METHOD

The method is simple enough. Having paid a visit to a research establishment we shall list a number of papers published by that establishment (or upon which it has based some of its work) relating to a particular field of endeavour. We shall endeavour to summarise very shortly the contents of those papers and, when appropriate, we shall mention ways in which the laboratory thinks practical use might be made of the results. We shall then refer to visits we have paid to a number of firms and other bodies manufacturing or using plant whose design or operation, we think, might be influenced by the published work of the laboratory. The comments of the firms will be published together, if available, with information of the before and after variety to show how the research work has actually been applied. In an ideal case the laboratory will have made a well-defined discovery and its application will have led to some substantial and obvious changes in industrial practice. More typically, it may well turn out, we shall be able only to cite a number of papers contributing to the understanding of certain phenomena and the firms making use of this information will only be able to report that the results are used in design calculations without being able specifically to provide any information of the before and after character.

We need to add that the value of the information gathered should be assessed in relation to the quite substantial element of selection involved in choosing subjects. For we have quite deliberately tried to choose subjects where the means of application of the new knowledge by industry can be reasonably well seen. To some degree this is unsatisfactory because it is the " high-faluting " very fundamental paper, least easily understood by practical men, that draws most criticism. We feel we must add, however, that whether by accident or by design or because our explanations as to

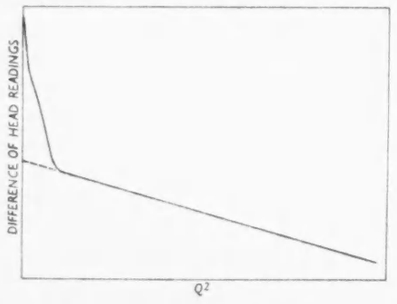


Fig. 1—Diagram illustrating the nature of the relationship between the readings of widely separated head gauges and the square of the flow rate when swirl is present at low flows. The readings of a gauge on the suction branch of the pump are shown. The other head reading is supplied in this case by a free surface and is therefore constant at a value equal to that corresponding to the point at which the dotted line meets the ordinate. Extrapolation of the straight-line characteristic as shown dotted reveals the true characteristic

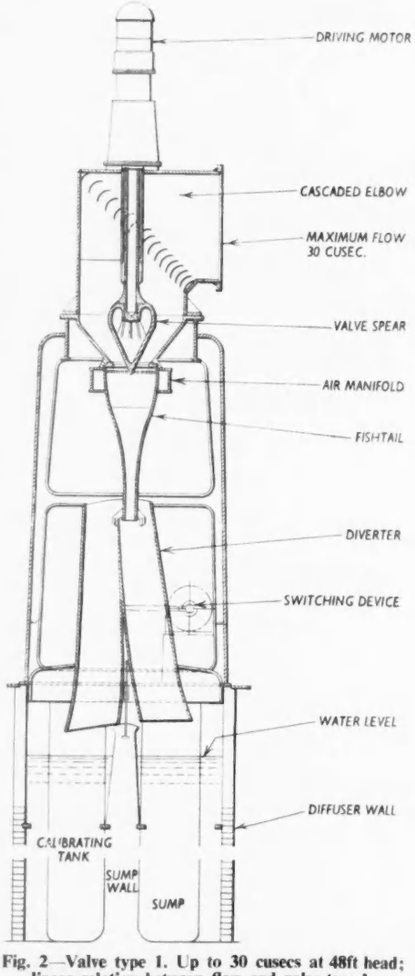


Fig. 2—Valve type 1. Up to 30 cusecs at 48ft head; linear relation between flow and valve travel

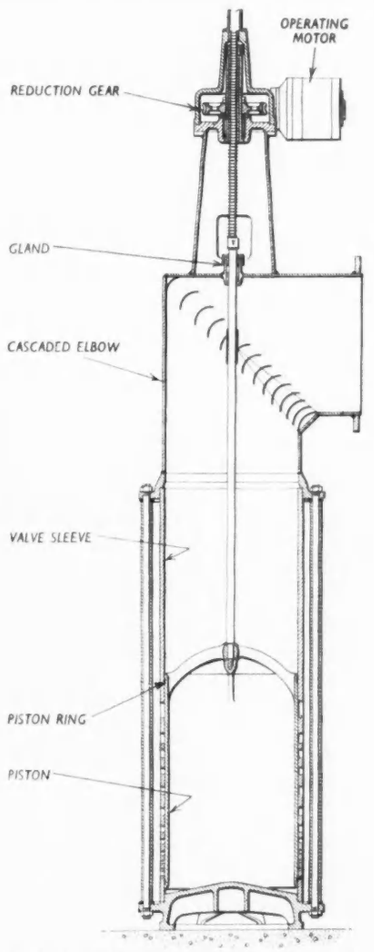


Fig. 3 (a)—Valve type 2. Maximum head 600ft; minimum 30ft; flows up to 30 cusecs

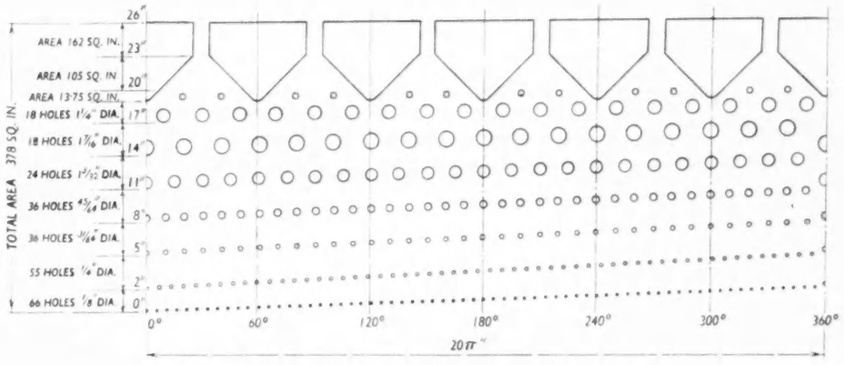

TOTAL AREA 378 SQ. IN.
AREA 162 SQ. IN.
AREA 105 SQ. IN.
AREA 13·75 SQ. IN.
18 HOLES 1¼" DIA.
18 HOLES 1⅞" DIA.
24 HOLES 1¹⁵/₁₆" DIA.
36 HOLES 4⁵/₁₆" DIA.
36 HOLES ¹¹/₁₆" DIA.
55 HOLES ¼" DIA.
66 HOLES ⅛ DIA.
0° 60° 120° 180° 240° 300° 360°
20π"

Fig. 3 (b)—Development of valve sleeve of type 2 valve

what we were about induced them so to do, those whom we have interviewed at research laboratories have not so far referred us to any papers of a very abstruse character.

Since at the majority of research laboratories many researches are usually being carried out simultaneously we do not intend to deal with all the work of a given establishment in any single article. Articles in the series will appear at irregular intervals because experience has shown us that it takes much time to gather material and how much time is unpredictable.

NATIONAL ENGINEERING LABORATORY: SOME HYDRAULIC ADVANCES

At the National Engineering Laboratory at East Kilbride a substantial amount of work has been done recently on hydraulic subjects. Two of the papers published should have been of interest especially to makers of water pumps and users of that equipment. They are: "The Prediction of Venturimeter Coefficients and their Variation with Roughness and Age," by Stanley Peerman Hutton, M.Eng., A.M.I.C.E., *Proc. I.C.E.*, April 1954 and "Eliminating Rotation Errors from Pump Head Measurements," by R. A. Nixon, B.Sc. (Eng.), *Water and Water Engineering*, Vol. 63, pages 9–11.

Additionally, there can be quoted, "A Simplified Integration Technique for Pipe-Flow Measurement," by Winternitz and Fischl, *Water Power*, June, 1957, Vol. 9, pages 225–234.

Venturi Coefficients

The first of these references is to a paper presented before the Institution of Civil Engineers. It is an excellent example of a short research paper. There is a somewhat dauntingly long list of references; but the mathematics are quite simple. In its specialised way the treatment is quite exhaustive. The author is primarily concerned to study the factors that may influence the coefficient C by which the theoretical discharge of a venturimeter must be multiplied to give the true discharge. He shows that C must be a function of external factors such as entry

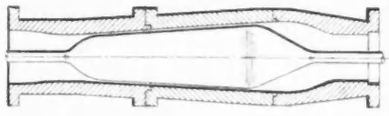


Fig. 4—Example of type 3 valve for heads up to 600ft and flows up to 20 cusecs. Wide range of cavitation-free operation.

velocity, distribution dependent on installation, pipe roughness, &c.; and of internal factors such as the venturi geometry, the contraction ratio, venturi entry-nozzle losses such as shape, roughness, &c., and venturi throat velocity distribution. One of these factors—it is a main conclusion of the paper—is variable with time. It is that of internal roughness; and dependent upon the material of which the venturi is made, the condition of the water and its pH value, initial falls in the value of C of the order of 1 per cent per year can occur. The rate of decrease lessens with time as the change from a smooth to a rougher surface is especially effective in altering C in the earlier stages. A semi-empirical method is suggested for calculating C.

Clearly, this paper may have proved valuable to any concerns needing to measure water flows accurately, such as pump manufacturers, water authorities and users of pumping devices. For errors in the value of C accumulating at a rate of the order of 1 per cent per annum could become substantial. If measurements are to be really accurate the conclusion seems inescapable that the meter should be calibrated regularly, as the laboratory recommends.

Pump Head Measurements

In the second reference the author points out that if swirl is present in the flowing water the head readings obtained from tapping points close to a pump may be in error. He proposes a method by which the error can be detected and a correction can be applied. He suggests that a second head gauge be fitted at a sufficient distance from the pump and in a straight run of the pipe where there will be little or no disturbance of the flow. Then, he points out, the difference between the head measured at this point and the head measured nearer the pump should be proportional to the square of the flow rate. As, in general, swirl will affect the reading of the gauge near the pump only at low flow rates, a graph plotted to indicate the relationship reveals that it is linear at higher flow rates. But departure from linearity occurs

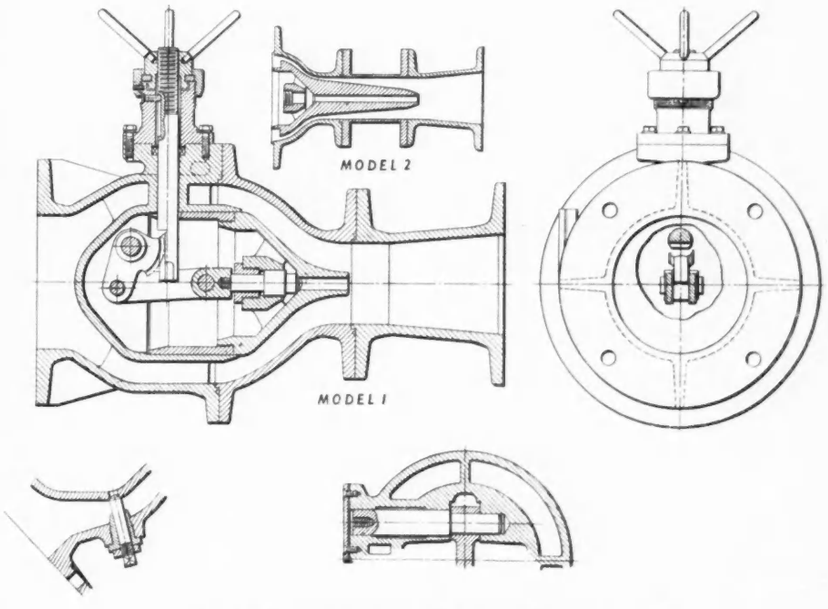


Fig. 5—Valve type 4. Up to 120ft head and up to 15 cusecs

at the lower flows where the error due to swirl becomes effective. Thus, not only is the erroneous nature of a reading revealed, but the correct reading can be derived from the graph, by extrapolation of the straight line, Fig. 1.

This appears to be a finding of real value to both makers and users of pumps. As swirl is more likely to occur on the suction side the method is particularly applicable on that side. But if some irregularity is suspected in the readings of a discharge head gauge there seems no reason why the method should not be applied on that side too.

Computing Flows in Pipes

The third reference relates to a paper in which methods of computing flows in pipes

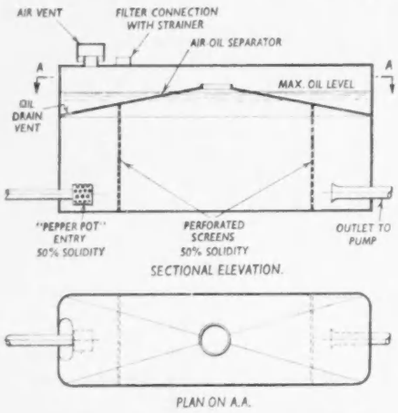


Fig. 6—Schematic design of suction tank. The tank must be long in proportion to breadth to allow air to reach the surface as the oil moves along the tank

from traverse measurements with Pitot tubes, current meters, anemometers, &c., are studied. A method is proposed which turns out, on the basis of experimental verification, to require measurements to be made at fewer points than has been usual heretofore but which yields results substantially more accurate for symmetrical velocity profiles and no less accurate for asymmetric profiles. It is regarded as such an improvement that it is to be incorporated in the new British Standard for Flow Measurement and the codes for testing fans, pumps and water turbines. It is a method which, it appears to the laboratory, has such advantages that any investigator using velocity area methods for obtaining flows should benefit from using it. There is in particular a marked saving of time not only in taking readings but in evaluating the rate of flow from the readings.

Design of Valves

Back in 1949 when the hydraulic machinery laboratory to be constructed at East Kilbride was being laid out, it became necessary to design certain special control valves for duties that were regarded at that time as unusual. A short study revealed the rather surprising fact that the information available in the literature and within industry was insufficient to enable the design and construction of the valves to be undertaken with confidence. A series of tests were therefore conducted on a number of models to elucidate the problems. The valves actually installed at the laboratory were designed on the basis of the results of the experiments. The following paper was published in January, 1954, " Some Model Experiments on Special Control Valves," by D. Firth and Leslie Young, *Proc. I.Mech.E.*, January 29, 1954.

The paper records the results of experiments upon a number of model valves designed to meet four different requirements, as follows:

Valve type 1. To control a flow varying from 1 to 30 cubic feet per second with a linear relation between flow and valve travel. To discharge to atmosphere under a constant head of 48ft of water and to provide a clean and symmetrical jet at all times.

Valve type 2. To meet the following limiting conditions; maximum pressure drop, 600ft of water; minimum pressure drop, 30ft; maximum flow, 30 cubic feet a second, minimum, 1; maximum power to be dissipated at any valve setting, 350 h.p. Discharge to main sump to avoid causing violent disturbances to the water surface.

Valve type 3. A maximum of 350 h.p. to be dissipated with pressure drops varying from a maximum of 600ft of water, and flow rates from 1 to 20 cubic feet per second. Cavitation free operation in the control valve over as wide a range as possible. The minimum pressure loss compatible with these aims.

Valve type 4. To be capable of controlling flows varying from 1 to 15 cubic feet per second with a maximum pressure drop of 120ft of water, and a minimum pressure loss as small as possible.

For reasons given in the paper a spear type of valve was preferred to meet the type 1 specification, as illustrated in Fig. 2. For the type 2 specification a piston was designed to be movable within a sleeve pierced with holes, the sizes of which were suitably graded, Figs. 3 (*a*) and 3 (*b*). To meet the type 3 specification a number of designs similar to those shown diagrammatically in Fig. 4 were tested. It will be seen that an axially movable conical plug is inserted in a conical body. It was eventually found that valves of type 4 were not needed. However, the paper describes results obtained on valves of the kind illustrated in Fig. 5 up to the time when further development was abandoned.

These valves were designed for the special purpose of a research laboratory. It seems very possible, however, that applications for some of the work recorded may have been found in industry.

Oil Hydraulics

Much work has been done at the National Engineering Laboratory on the subject of oil hydraulics and a number of papers have been published. Only one reference is given here however—" An Old and a New Look at Oil Hydraulics," by D. Firth, *Compressed Air and Hydraulics*, October, November and December, 1958. The paper was originally presented at the first European Fluid Power Conference.

This is a paper which, in effect, surveys the design possibilities of a simple oil hydraulic circuit. To anyone unaware of the nature of the work on oil hydraulics being done by the laboratory it could well act as an introduction. Amongst other matters attention is emphatically drawn to the importance of preventing air from becoming entrained in the oil. The troubles which arise from air entrainment are due to the greatly increased compressibility which is its consequence. For example, a mixture containing 5 per cent of air by volume compressed from 250 lb to 4400 lb per square inch decreases in volume by about 23 per cent. Air-free oil would decrease in volume by only 2·42 per cent. In a badly designed system the air content of oil can rise as high as 18 per cent. This leads the author to consider the design of the suction tank, a device which can only too easily be responsible for aerating the oil, and he provides the diagram printed here as Fig. 6 to illustrate good design. He also studies the suction pipe layout, pointing out that on the suction side static pressures are low and therefore that the losses caused by velocity effects are there important. " It is not unusual to find the head loss in the suction line, by causing very low static pressures at the pump inlet, entirely responsible for lowering pump efficiencies and causing noise." The paper includes a number of comments, for example, upon the accuracy of gauges and of flow and torque measurements.

A number of firms and organisations have been asked to comment. Their contributions follow.

W. H. Allen, Sons and Co., Ltd., Bedford

The Venturimeter.—No attempt has so far been made to apply the conclusions of the paper, partly because the meters in use are not easy to get at for recalibration. But if and when the test-bay piping is re-arranged the meters will certainly be designed for easy removal; and whether or not a more wholesale pipe re-arrangement takes place consideration is actively being given to a re-arrangement of the venturis. No attempt has been made to apply the formula derived in the paper. The opinion, in fact, was expressed that the main point brought out by the paper is the need for much more frequent calibration than had been thought to be necessary in the past. It is regarded as very probable that the meters are now yielding erroneous results. The situation is regarded as serious because, quite apart from contractual liabilities, works' tests can be the basis for future designs and close accuracy is therefore essential.

Head Readings.—Very probably the firm appreciated the important influence of swirl in affecting head gauge readings earlier than the N.E. Laboratory. Many years ago a very large mixed-flow pump was under test in the test-bay on air instead of water, as it was wholly impracticable to water-test it. On one occasion, when it was running at a low delivery rate, one of the testers happened to have an empty paper bag sucked out of his hand into the short suction pipe. He naturally expected to see it discharged in due course down the shop. Instead it was offered back to him just above floor level. It is recorded that thereafter all and sundry projected paper bags into the suction pipe at various levels; and that the chairman himself " came down " to join in the fun! The event naturally led to a more complete investigation of the flow pattern upstream and downstream of the impeller.

The determination of the true characteristic of a pump is, of course, necessary when the head and delivery are to be variable in service and especially important when pumps are to operate in parallel. A drooping head characteristic at low deliveries can lead, for example, to hunting. The method suggested in the paper has been applied in the test-bay and a typical result is shown in Fig. 7. But, unfortunately, it is not often possible to apply the technique on site; and it is, of course, just where on-site conditions are difficult that some means of detecting errors in head readings would be especially welcome. For, because of pipe bends, &c., close to the pump, ordinary head gauge readings become quite unreliable, so that the pump on site may appear to have characteristics that do not accord with those recorded by a test-bay test and may, indeed, suggest that the efficiency of the pump is well below that guaranteed, possibly leading to acrimonious argument. Consultants have been known under such awkward circum-

stances to declare that the manufacturers should have allowed in the design for the effects of the pipe lay-out; to which the manufacturer can only reply that tests are meaningless under such conditions. In this firm's view it cannot too firmly be stressed that on-site is not the place to carry out acceptance tests.

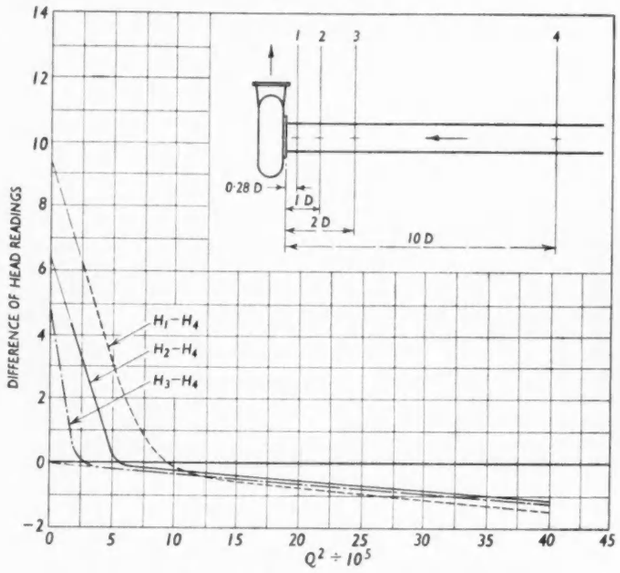


Fig. 7—Difference of head readings by suction side gauges plotted against quantity pumped. The influence of swirl is very marked

The paper actually refers only to the measurement of suction head. But it was pointed out that swirl can occur on the discharge side, especially in mixed-flow pumps. Gratifying, but untruthful, results can be obtained, for example, if the lay-out is such that a swirl is set up in the volute; and the results under such conditions can become more and more gratifying the greater the delivery rate of the pump!

The swirl set up in the discharge branch of certain types of mixed-flow pumps is not unidirectional, so that it may be found that the rotation at large quantities is of opposite hand to that of small, and there are even cases where points can be found on the characteristic where a double swirl in opposite directions is taking place in the volute and discharge branch. Needless to say, the direction of rotation of the swirl cannot immediately be decided from the head reading as the centrifugal head produced will naturally be independent of the hand of the rotation.

Current Flow Meters.—All the foregoing remarks have relevance to the measurement of flows by current flow meters. If the claims made by the Laboratory are substantiated (as is likely) the method suggested in the paper would, it was felt, be widely adopted. No actual use of it has so far been made by this firm.

Valves.—If and when the test-bay lay-out is altered there is no doubt that this paper would be studied with care. A preliminary design has been done on a type 3 valve—see Fig. 8. But the trouble with this kind of valve is its length. The design shown in the photograph illustrates how the same principle can be used with a less acute angle. The valve would be accommodated in the bottom of a tank and operated from the far side in the manner shown. It should be emphasised that the design is very tentative. It is a study representing a possible solution to a known future problem; that is all.

WORTHINGTON-SIMPSON, LTD., NEWARK

The Venturimeter.—Like the previous firm this one was disturbed by the revelation in the paper of the rate of change of the coefficient of a venturimeter with time, especially as the error introduced is of a kind that will suggest the pump has a higher efficiency than it really has. The only real cure, it is felt, would be to get the makers to recalibrate all venturimeters at frequent intervals.

Head Readings.—The influence of pipe lay-out upon recorded pump performance was stressed. The firm is planning a study of a large pump with a reflux valve very close to the pump outlet. The lay-out is likely to be similar to that shown in the accompanying Fig. 9, and a complete survey of the distribution of flow under a variety of head conditions is planned. As an example of the errors that can creep in when head gauges close to a pump are trusted, it is worth recording some observations made during a culvert test programme. The lay-out is shown in Fig. 10 and some details of the pump suction arrangement in Fig. 11. "Perspex" windows in the culvert allowed observation.

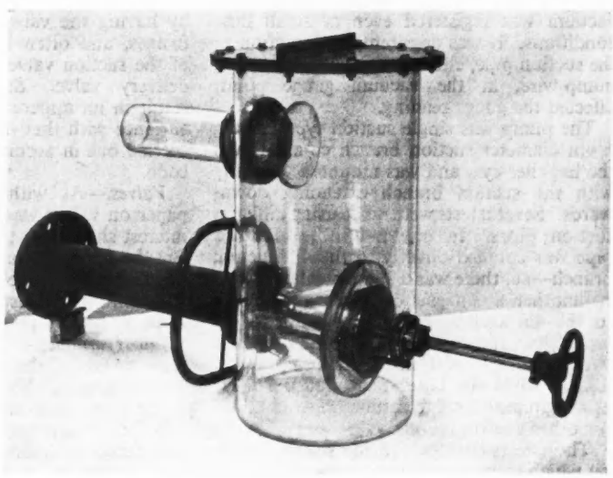


Fig. 8—Tentative design for a modified form of Type 3 valve. The taper of the cone, it will be seen, is much sharper than in the laboratory example

Metal flags mounted on the culvert floor around the suction pipe bellmouth indicated a considerable degree of rotation, counter to the pump rotation, at capacities greater than the best efficiency capacity. This was particularly observed at maximum pump capacity when a central axial core could be

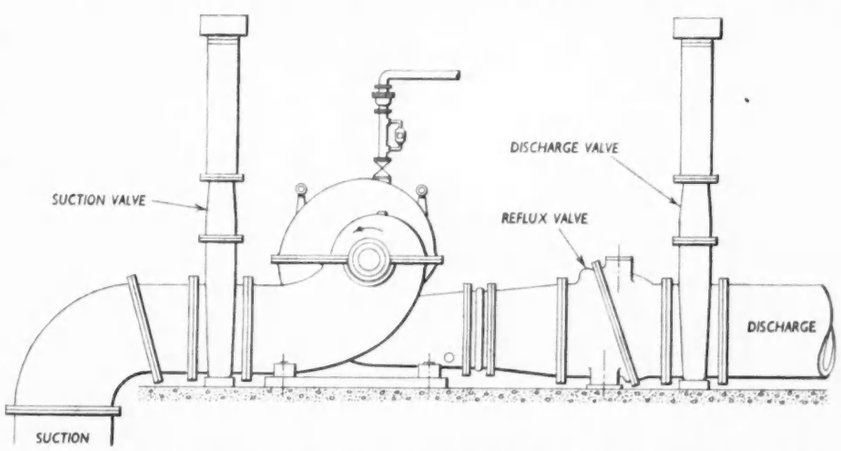


Fig. 9—Probable arrangement of pump and valves for study of distribution of flow under various conditions of head and delivery by Worthington-Simpson, Ltd.

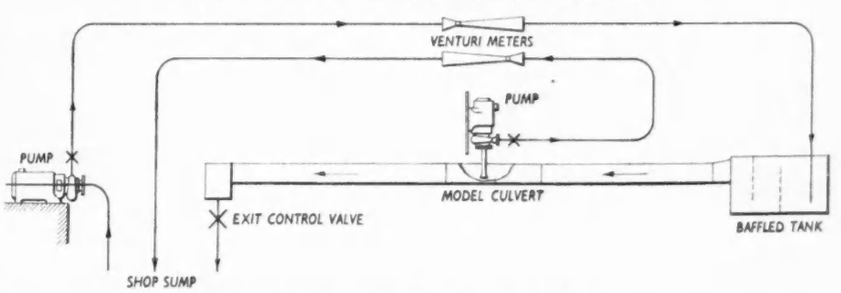


Fig. 10—Layout of model culvert test equipment

seen rising from the culvert floor into the suction bellmouth.

It was apparent that false readings were being obtained, from the vacuum gauge connected to the pump suction flange, presumably due to the induced rotation in the suction pipe. During several tests when the water level varied from 11in to 15in above the culvert floor, and the vacuum gauge point was 19in above the culvert floor—i.e. a static lift of 4in to 8in, no vacuum was registered even at small flow conditions. It was apparent that rotation in the suction pipe, either pump-wise or counter pump-wise, at the vacuum gauge point, affected the gauge reading.

The pump was single suction type, having a 4in diameter suction branch co-axial with the impeller eye, and was mounted vertically with the suction branch extending downwards. Several tests were made using different suction pipes. In one a 2in bellmouthed pipe was coupled directly to the 4in suction branch—i.e. there was a sudden enlargement. In another a 3in suction pipe was coupled to the 4in suction branch by a 3in to 4in taper pipe and so on. The former of these two tests registered no vacuum up to 65 g.p.m., while the latter registered 0·9in Hg at 40 g.p.m. Similar results were obtained for other conformations.

These tests did not provide sufficient data on which to build a theory of rotation in the suction pipe and impeller approach; and the subject has not been further pursued since the object of the series of tests in question was to establish suitable suction culvert contours and proportions for a battery of large circulating pumps, and not to study pump performance. During the tests here reviewed the culvert was used as a sump, and there was no flow other than that induced by the pump on test.

Flow Measurements.—The paper has been read and its conclusions noted. But no opportunity has so far arisen to try out the method. It is regarded as potentially valuable through the reduction of time and cost and complication.

Site Tests of Large Pumps.—Pipe and valve arrangements are not always ideal on site, and are frequently far from ideal. The firm has been concerned recently in a case where the site test results were rather poor, although the pump design was based on well-established data and experience. This led it to suspect false gauge readings due to the gauges being in close proximity to valves, particularly a multi-door reflux valve. This feature may have a very marked influence on the apparent performance of comparatively low head pumps. The firm intends to investigate this matter in its test department, when opportunity arises as already mentioned.

Some site arrangements are even worse by having the valves directly on the pump flanges, and often having a bend upstream of the suction valve and downstream of the delivery valve. Such arrangements may result in an apparent pump performance at variance with that indicated by a works test carried out in accordance with the B.S. test code.

Valves.—As with the previous firm the paper on valves was felt only likely to be of interest should the test-bay be reconstructed. But the comment was made that the common-or-garden screw-down valve has little to commend it in a test-bay where close control of heads and outputs is desired.

Oil Hydraulics.—The firm's representatives were aware of the work being done at the Laboratory on this subject. The firm is at present engaged in the preparation of a scheme for large-scale tests of oil pumps and associated oil hydraulic problems. Notably, it is suspected that the viscosity of oil is varied by air entrainment. Air entrainment is certainly of importance to turbine builders as, the firm felt, all must have experienced troubles from foaming at some time or other and calibration of the delivery of a lubricant pump can be rendered very erroneous by air entrainment.

The representatives of this firm went out of their way to emphasise the helpfulness of the Laboratory in a number of ways.

RUSTON AND HORNSBY, LTD., LINCOLN

Some apology is due to this firm at the outset because through no fault of ours or of the firm's we were able to give only very short notice of our coming; with the consequence that the conversation tended to wander off into technical discussion of subjects which, though deeply interesting, were irrelevant to our present purpose.

Head Readings.—This firm like many others has experienced difficulties in obtaining accurate head readings, undoubtedly due to the presence of swirl. The tendency when troubles are experienced with pumps is to consult, not the National Engineering Laboratory, but the British Hydromechanics Research Association Laboratory. A typical example of that latter Laboratory proving helpful occurred recently. Some sizes of pumps in a new range failed to yield the expected output. The impeller shown in Fig. 13 was designed to give 400 g.p.m. at a gross total head of 30ft, but it actually delivered only 300 g.p.m. B.H.R.A. recommended a rounding of the trailing blade edge, as shown in Fig. 14, on the ground that it would alter the exit angle into the volute. This action proved completely successful.

Another instance of B.H.R.A. helpfulness was provided by the adoption of a suggestion which cured a persistent trouble of " Brinnelling " of the swash plate of a five-cylinder

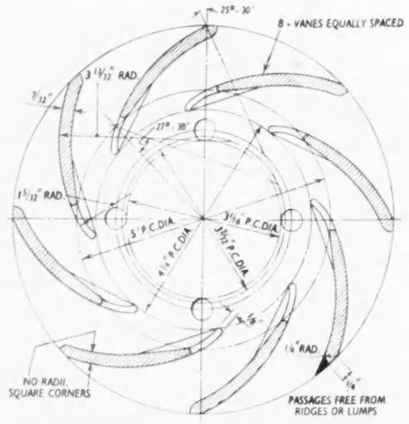


Fig. 13—This impeller, intended to yield 400 g.p.m. against a head of 30ft, yielded only about 300 g.p.m. Simple modification ; Fig. 14 gave the required duty

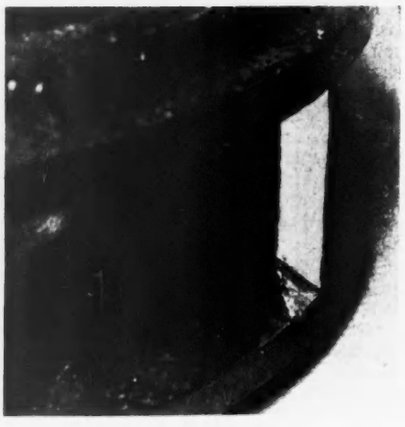


Fig. 14—Centrifugal pump impeller, trailing blade correction

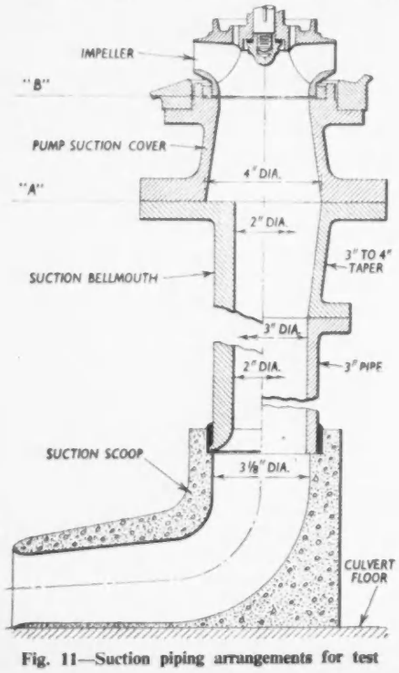


Fig. 11—Suction piping arrangements for test

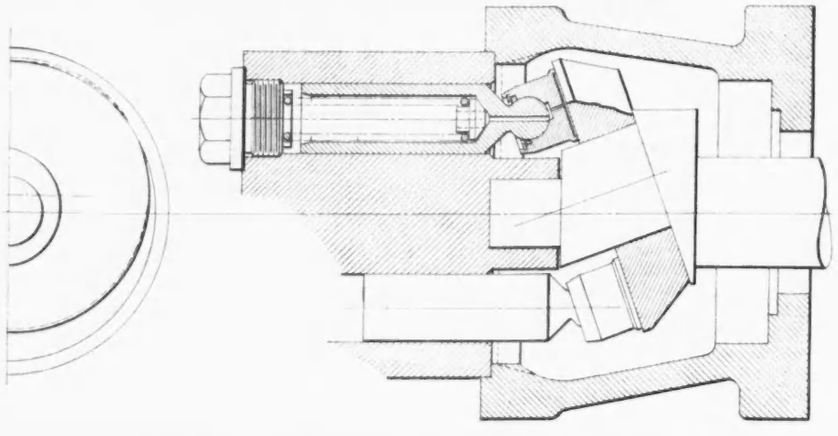


Fig. 12—Assembly of swashplate pump with hydrostatic slipper bearings

swash-plate pump with plunger ends running in line contact with the swash plate through taper-ended plungers matched to the angle of the swash plate. As shown in Fig. 12 hydraulically balanced slippers were substituted and proved fully successful. The material pumped is diesel fuel, which serves as a lubricant of the running gear.

Oil Hydraulics.—The opinion was expressed that the study of oil hydraulics is necessary by all oil engine manufacturers, especially in relation to the performance of injection pumps and injectors. It is particularly necessary to the firms which make their own fuel injection equipment. It was stressed that much help and advice had been received on this subject from the National Engineering Laboratory and it had proved of high value.

The firm has under development a swash-plate pump for high oil pressures, and trouble has been experienced from surging at certain speeds and deliveries. It is suspected that the air content of the oil may have something to do with it, and interest was consequently expressed in the design of oil storage tank suggested in the paper.

(*To be continued*)

Future of Road Transport

Last week, Mr. Albert Enticknap, F.R.S.A., M.I.R.T.E., presented to the Institute of Road Transport Engineers in London a study of historical trends in transport. Postulating that it was desirable for Great Britain to remain active industrially, he developed the details of a possible long-range road haulage system. The lecture is abstracted below.*

IT is said that the British are a very conservative people; by this we may interpret that we are very slow to adjust our method of thinking to suit new and strange conditions. We prefer to base our new thoughts upon past experiments and experience, we are always inclined to find as much fault as possible with new ideas, because such ideas interfere with our existing methods and way of life.

The English Channel has been our great defensive moat against invaders; in the past it has been an asset to our survival, in the future it may be our greatest enemy, unless we are prepared to accept the new world and its challenge to us.

Recently, we have seen constructed throughout Europe superb roads stretching from the English Channel to the Atlantic Ocean and Mediterranean Sea.

As history so often repeats itself, these highways are for the defence of the West against the East, and ensure rapid troop movements, &c.; however, as they now exist and are growing with rapidity it is as well to use them for peaceful purposes, and this is, of course, commencing.

In the past road and rail transport have delivered the products from factory to seaport; thence by ship to the port nearest to destination, then once again by rail or road to the customer, but such process is time-wasting and expensive.

Our prosperity is largely due to the development of our inter-continental shipping organisation and we must agree that the past shows us that it served us well. However, this will not help us in the future; we must be prepared to change our opinions and appreciate that this mode of transport is often uneconomic, what we require are an entirely new approach and much courage and determination. It is a very unpleasant thought to realise that a large proportion of our shipping, which is even now lying idle, will never again be required, as work for it will become increasingly difficult to obtain.

In the past, most of the cities in Europe grew up beside rivers and close to the sea. This was convenient and practical, however, for as raw materials became more expensive to transport, towns grew up around the factories close to where such raw materials existed, whilst in other cases many towns grew because of their ability to develop industrial processes and most of these conurbations are not situated within easy access of waterways. Railways and canals helped, but as we have seen, such means for transport are unable to handle their responsibilities economically.

Transport by road has temporarily eased this difficult situation, at least in England; however, it would appear that road transport has now, with the new roads, adequate opportunity to expand to the Continent and then farther into the Middle East.

Inter-continental haulage is the obvious answer to our export problem: at least this offers us ways and means to reduce the cost of our products upon the European Market and we must take advantage of this.

Design of Vehicle

For economic reasons it will be necessary to have vehicles with as large a carrying capacity in ton-miles as is possible, and this means some difficult technical problems.

Such a vehicle will require the ability to haul loads of not less than 60–100 tons, at speeds of 40–50 m.p.h., with reliable and efficient long-range operation. It must be easy to service for quick change-round, and possess simplicity for maintenance when long distances from base.

It would, of course, be impracticable to carry such loads upon a single chassis, therefore we require a multi-unit vehicle carrying, say, 40 tons per unit, each unit being independently motorised but controlled from the leading unit, as is railway practice.

From railway, marine and aircraft practice we must use the best ideas they may offer, condensing these, utilising them to the best advantage, and incorporating suitable ones in chassis design and prime-mover control.

Power Unit.—The diesel or C.I. engine has grown in popularity in Britain over the past thirty years; it is now established as the prime mover for our heavy road transport vehicles and would appear to be suitable for the development herewith anticipated.

However, this is not so; it has the ability to produce the necessary torque, has reasonably long life and is economic on fuel consumption, but its power-to-weight ratio makes it unsuitable for really heavy vehicles on long distance work.

Assuming the loads carried to be those already mentioned we shall require engines of 350 b.h.p. or more, of the highest possible power-to-weight ratio and capable of operating on various grades of fuel.

Necessary factors will be the ability to obtain rapid acceleration, ease of maintenance, engine drag to assist braking, ease of starting under varying conditions, and smooth running to ensure long life to transmission, tyres and chassis. A lightweight, high-speed petrol engine would be ideal. It might be an eight-cylinder "V" design or horizontally opposed and running at some 6000 r.p.m. at full load. The dry weight of the power unit should be in the region of not more than 8 lb per brake horsepower.

Overhead valves and overhead camshafts would be needed to avoid valve bounce, allowing continuous accuracy in valve timing, especially necessary under arduous conditions of full or near-full loads, and ease of maintenance. The camshafts should be gear-driven, again giving longer life and ease of maintenance. The exhaust valves, exhaust manifolds and pipes, flanges and silencers, also cylinder-head gaskets, to be made from austenite stainless steels for a safe and long working life.

The engine must be designed for a reliable and safe working life of 200,000 miles or more. This calls for much care in both design and manufacture, allowing minimum machining and fitting tolerances and the use of highest quality materials. High standards of inspection during manufacture would be necessary; this applies also to cleanliness. During its normal life we must, of course, allow for adjustments to overhead-valve mechanism, decarbonising, &c.

Fuel control may be by carburetters or petrol-injection pump, preferably the former, as this is more reliable and easier for maintenance; however, later, when we are able to produce an efficient petrol-injection system, this should be used with a corresponding increase in compression ratio and a possible reduction in weight. Lubrication should be with a high pressure, precision, gear-type pump; the lubricating oil being drawn from a separate tank, through adequate filters, circulated around the engine, through inter-coolers and back to the tank. This would allow the carrying of a large quantity of oil for long runs between stops, adequate cooling of oil after use to ensure long engine life, and separate instruments for the crew to read oil pressure, temperature and quantity available. The inter-coolers may be controlled by the crew or be temperature controlled to suit road and weather conditions.

Engine cooling should preferably be controlled by air flow from a ducted fan, and the mass flow be varied to suit conditions. Such air cooling would require ducting to and surrounding the engine, designed aerodynamically, with ease of maintenance and made from light alloy. This could be obtained by using an electric motor, or oil-hydraulic device and varying the flow, as examples, by altering blade pitch, by a hydraulic flywheel fan drive or a relief valve in the ducting.

It would be preferable not to rely upon a liquid for engine cooling, as this may prove troublesome under the varying conditions anticipated. Air from the engine-cooling fan may be used for cab cooling or for warming by means of heat exchange from engine and exhaust system.

The electrical system should have two generators to ensure adequate reliability for long periods away from base; the output from each could be controlled when both are efficient, but if one should become unserviceable the other could then operate at full load. Each should be driven separately by gears or a multi-belt. The compressor may be driven direct from the engine and designed to give adequate supply to suspension, brakes, gear control and possibly brake cooling. A further addition to the air receiver must be a means for

* Alpha Motors, Ltd.

affixing an air line for checking tyre pressures. All electrical equipment such as sparking plugs, coils and condensers should be duplicated for safety and reliability.

Special attention must be paid to voltage-control regulators and batteries to ensure their reliability under extreme conditions of dust and heat.

Bogies.—The power unit will be an integral part of the bogies, as in locomotive practice, the bogie being able to swing to a given radius to assist in manœuvring when its chassis is part of a multi-unit road train. It would also require steering mechanism. Alternatively, if each bogie is fitted with normal automatic steering control, this would suffice. However, it would probably be best to use both.

Turn-round times would be much shortened by removing the faulty bogie, or bogie-cum-prime mover carrier, and immediately replacing with a reconditioned unit ; the original unit would then be repaired and ready for work again without inconvenience to the working chassis unit.

It follows that each bogie is a unit, inasmuch as it incorporates axles, steering, suspension, brakes, and the trailing bogie carries power units and transmissions.

When a vehicle is being towed as a powered trailer it will be necessary to ensure that the steering is in geometrical sympathy with that of the towing vehicle.

Chassis Frame.—Lightness and strength of design for long wear must be considered and here we can borrow ideas from aircraft designers ; as an example, a chassis construction in light alloy similar to the geodetic design as used on the Vickers " Wellington " bombers of 1940–45, or a tubular construction similar to that design which is proving successful as used in the new diesel-hydraulic locomotives of the Western Region, British Railways. A light, fabricated, cantilever construction would save considerable weight and if well designed would give the necessary strength. As the bogies are individual units, it is necessary for the chassis frame to carry only the load and auxiliary equipment, such as fuel and oil tanks, inter-coolers, ducting, &c.

It should incorporate the master control and lubricating-oil reservoir for an automatic or semi-automatic lubrication system to ensure long life and regular lubrication of all rubbing surfaces. Further, all electrical wiring should be in conduit fixed to the frame and with push-in plug-type connections for all wiring points ; this would also assist where thermocouples are necessary, such as for gearboxes and differentials.

All metal parts must be treated either electro-chemically or metal sprayed against corrosion and extreme temperature changes.

The chassis frame must be designed to incorporate such self-loading or unloading devices as may be considered necessary, also to be easily maintained and inspected ; and welded construction should be used extensively to give long life.

There should be attachments or a built-in jacking system, designed to ensure ease and safety of wheel changing, especially when the vehicle is loaded and standing on a steep gradient, when the use of normal orthodox equipment would be difficult, dangerous and time wasting.

Transmission.—A multi-speed gearbox will be required to maintain the torque necessary for starting away and hill climbing ; possibly two boxes will have to be available, incorporating sixteen gear changes, including overdrive, and these must be automatic to reduce driving fatigue and responsibility.

Hydraulic flywheels and electro-magnetic clutches will be necessary for the automatic gearboxes, to allow the driver to bring in the trailer power units when required.

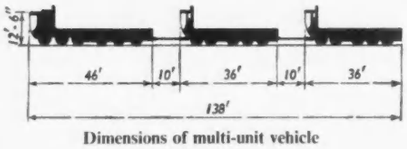
Many such gearboxes are in use by American truck operators and could be adapted to meet our requirements. The power unit and gearboxes could be arranged " amidships " in the chassis, with a short propeller shaft to a take-off box, from which two propeller shafts would pass to the first and second differentials of the rear driving bogie.

Suspension.—Air suspension could be in the form of air sacks or bellows and, as already stated, there would be adequate compressed air available. Such suspension could be adjusted by the crew to suit temperature, road and load conditions, which would ensure long life to the vehicle. We must appreciate that the vehicle may travel light perhaps 500 miles or more to pick up loads, and much wear would occur if the suspension could not be adjusted. After considerable operating experience, the Americans have found this to be correct !

Air supply to suspension units would have to be adjusted to suit altitude conditions experienced when operating in mountainous country, and this can be made automatic.

Tyres.—As the axle loading will be 7 tons and all but one axle will be fitted with steerable wheels, it would be impracticable to fit the normal twin tyres which would be advantageous owing to their small diameter. Consequently, single tyres must be fitted, 15·00 × 20, 20 P.R., these having a maximum load rating of 94 cwt at an inflation pressure of 90 lb per square inch. Two such tyres on any one axle would provide a maximum axle-tyre capacity of 9 tons 8 cwt, which is well in excess of our requirements.

As these tyres have an overall diameter of 4ft 2in, this demands a minimum height of loading platform of about 5ft. Fortunately, as air suspension is suggested, this would ensure that the loading platform is kept to



Dimensions of multi-unit vehicle

this uniform height irrespective of the load weight carried. The tyres are designed for the load mentioned and a speed of 30 m.p.h.; however, it will possibly be necessary for the tyre manufacturers to design for speeds well in excess of this. Adequate cooling air will be necessary to ensure that tyre temperatures are kept to a minimum suitable for long life, and the design of mudguards or wings should allow for this.

Driving Cab.—The towing vehicle would require an extensive cab, able to house the crew of two in comfort under all climatic conditions and to reduce driving fatigue.

It would be divided into two compartments, forward being the driving section with comfortable seating, preferably adjustable armchair-type seats, instrument panel situated to be observed by both crew members and a large panoramic-type windshield free from any obstruction and giving adequate vision forward, to the sides and downward to the road.

The instrument panel should show whether or not the other engines in the train are working and any other important relevant information concerning them, whilst periscopes for rear viewing should be fitted for both of the crew. Temperatures of the rear axles and gearboxes, brake-storage-cylinder pressures and any information that will assure the crew that they are aware of exactly how the machinery in their care is performing should be clearly indicated.

The rear of this cab should house bunks, toilet facilities, wardrobe, small cooker ; the whole to be insulated against climatical temperature changes. If by chance the train was snowbound, it should be possible for the crew to survive under comfortable conditions until help arrived.

The trailer cabs need only be similar to those now in use, large enough for two men, suitable for local deliveries, but designed for extreme climatical temperature changes and for good vision.

It would be advisable for these cabs to be designed to be easily removable, so that if extended loads are necessary these can easily be carried by removing the cab.

Spare cabs can be kept under the control of local traffic-control officers for use under such conditions.

Is it Economically Practical ?

If we assume that the vehicle train previously described carries a load of 100 tons then ten such road-vehicle trains will carry 1000 tons. Assume also the average journey to be 1000 miles from the French port of disembarkation, and that good weather and road conditions prevail.

Let us take 30 m.p.h. as the average speed for both outward and return journeys = sixty hours. Therefore sixty hours, plus resting, unloading, change-round time and delays could be analysed as follows :

Driving ten hours per day = six days.

One day for resting upon reaching destination = seven days.

Unloading and changeover times, also vehicle check, say one day = eight days.

Assume times quoted are underestimated, therefore add two days = ten days.

Therefore total time out and home = ten days.

In a year of 365 days the vehicle would be able to complete at least thirty-six journeys of 1000 miles each.

Therefore allow ten days per 1000 miles travelling time.

Considering these facts and placing them against export tonnage from the United Kingdom to Europe for 1957 :

For 1 per cent it requires ten vehicles to make 110 journeys per annum.

For 5 per cent it requires ten vehicles to make 550 journeys per annum.

For 10 per cent it requires ten vehicles to make 5500 journeys per annum.

To Middle East :

For 1 per cent it requires ten vehicles to make 16½ journeys per annum.

For 5 per cent it requires ten vehicles to make eighty-two journeys per annum.

For 10 per cent it requires ten vehicles to make 165 journeys per annum.

Taking the figure of 10 per cent divisible loads to Europe = 1,102,300 tons, it would require 307 road-vehicle trains. Similarly, to the Middle East it would require forty-six such vehicles, making a total of 353 road-vehicle trains.

Let us consider an order for 100 such road-vehicle trains. Assume the cost of only one 35-ton payload vehicle to be £15,000. Thus the total capital cost of 100 road-vehicle trains would be £4,500,000. The life of such a vehicle would be, say, eight years before replacement. At thirty-six journeys per year of 1000 miles each this would give a life of 288,000 miles per vehicle, or 288 journeys. Therefore the basic cost of each vehicle per journey would be £156 5s. or 3s. 1½d. per mile.

From investigation the average cost of

fuel (petrol) in Continental countries is 5s. 6d. per imperial gallon. Assume the fuel consumption to be 3 m.p.g. Therefore the fuel cost per mile would be a little less than 2s., say, 2s. per mile. Inquiries show the basic insurance cost to be 8¼d. per mile.

We would require highly skilled crews, the cost of which could be as follows :

Senior driver	£2000 per annum
Second driver	£1700 per annum
Two qualified local drivers for delivery of powered trailers at drop off points	£2000 per annum
Total	£5700 per annum or 3s. 2d. per mile

It would be necessary, if a fleet of 100 trains was operating in Europe, to have traffic offices, &c. Therefore, let us assume ten such offices at important trading centres in Europe. The staff required at each office would probably be, an office traffic manager, assistant and typist, and for ten such offices, the cost would be :

Salaries	£19,000 per annum
Rent, lighting and office equipment, &c.	£3,500 per annum
Total	£22,500 per annum

Which equals 1½d. per mile.

Therefore the basic operating costs per mile would be as follows :

	s.	d.
Vehicle train	3	1½
Labour	3	2
Insurance		8¼
Traffic control		1½
Fuel	2	0
Total	9	1¼

Assume the total overheads of the whole organisation to be 200 per cent, this to include headquarters, staff, offices, workshops, &c. Then the total operating cost per mile would be £1 7s. 4¼d., and the suggested delivery price, say, 6d. per ton-mile.

Vehicle carries load of 100 tons=£2 10s. per mile.

Outward journey of 1000 miles, revenue=£2500.

Double this for return journey=£5000.

From this analysis we may deduce that such a transport system would be economically practicable.

International Transportation Agreements

During August until September, 1949, an international conference was held at Geneva, Switzerland, when much progress was made concerning the future of road transport, and most of the world's nations agreed upon such problems as width and type of road, road signs, rules of the road, sizes and conditions governing some aspects of vehicle design and numerous other points, including a standard design of driving licence.

From this very complex and exacting report (*The United Nations Conference on Road and Road Transport*), which is printed in English, French and Spanish, a considerable amount of information is available to act as a guide to future vehicle design, and assist in conveying some idea that, in the foreseeable future, transport will become international, therefore our own ideas should be linked to this in preparation for the future.

The specified overall width recommended for road vehicles is a maximum of 8·20ft, and the maximum height of 12·50ft. Further, the axle loadings are to be not more than 8 metric tons (17,600 lb) and it is suggested that the maximum length of a train of vehicles should not be more than 72ft. However, two trailers are permitted and it would appear that the type of motorised trailers herein described may possibly be accepted, although a train of three would exceed this specified length.

The ability with steerable bogies to have good manœuvring characteristics would possibly allow the maximum length of a single vehicle to be 46ft, as specified for articulated vehicles. Therefore our vehicle might be 46ft overall, 8·20ft wide, with six axles divided into two steerable bogie units.

As the powered trailers do not require such a large driving cab as that of the towing vehicle, they could therefore be considerably shorter, say, 36ft by 8·20ft wide. This reduction in length would assist them when making local deliveries at their drop-off point.

The length of a vehicle train would then be as follows :

Towing vehicle	46ft
Powered trailers at 36ft each	72ft
Space of 10ft between each unit	13ft
Total overall length	138ft

Although the length is in excess of the specified suggested length of road-vehicle trains, the outfit would be highly manœuvrable and controllable ; provided it is kept to the main motorways between cities, this should be satisfactory and permissible.

It is now necessary for us to observe the advantages of this design of vehicle in actual operation.

Why Now ?

This question prompts us to consider if this matter is of urgency, and to do so we must consult a map of Europe. The Germans are in the fortunate geographical position of being sited in the centre of Europe ; they have excellent roads spreading across their country which connect up with those of others since constructed. They are already situated in the very heart of the European potential transport area and have no water barrier between themselves and other neighbouring countries ; the only barriers existing are man-made and, therefore, are subject to change. We, on the other hand, have the English Channel, a natural obstacle subject to weather conditions such as fog, heavy seas and winds which may interfere with punctuality—an essential for efficient transport operation.

Experience shows that the originator of new ideas in business usually succeeds in obtaining the " lion's share " of any potential market, and the " crumbs " are left for the copyists.

This state of affairs might well exist if the Germans themselves act and put into practice such an original scheme as is described herein, and once having established goodwill, with experience they would be almost impossible to compete with economically.

The Germans are good organisers, they are continually seeking new ideas for their betterment, fortunately they lack our experience, in the operating of transport, and for this reason we should give serious and immediate consideration to any scheme which would appear to promote our trading within Europe. Further, the necessity of selling our goods within these markets, with ability to deliver to the customer, should give us an added advantage. European competition is becoming increasingly aggressive and this will permit us to compete on their own ground.

It is reported that many of our shipyards and shipping companies are suffering through this competition, and the outlook does not suggest that this will weaken in the future. This being so, it would appear an excellent suggestion for some of our shipyards to change their productivity from shipbuilding to road-vehicle building. Thereby the exports of new heavy road vehicles would not be interfered with ; and the production from existing plants could be carried on without fear of competition from these proposed new road-vehicle trains, as there will always be a market for the types of vehicle now operating. After all, in Lancashire the textile manufacturers have had to change their productivity to meet modern changes, as have also the coalminers in South Wales and producers in many other industries.

If the shipbuilders wish to exist as successful businesses some of them, no doubt, must change their products. Any retardation of shipbuilding must have its eventual effect upon the shipowners. Here then is their opportunity to re-establish themselves as road transport operators in this special field ; they are used to handling large quantities of goods over large areas and their experience and contacts would be invaluable to such a project as that outlined.

It can be said that such a scheme can be only to the ultimate advantage of commerce and industry.

Is There an Alternative ?

Let us consider the aeroplane, helicopter and V.T.O. machines as possible alternatives. An aircraft capable of lifting loads of 100 tons has yet to be built, the best freight aircraft available in the foreseeable future may take loads of about 30 tons. It is restricted, inasmuch as it can fly only from airport to airport ; its operational time is restricted by weather conditions, it is a complex machine and requires much maintenance and careful treatment. There would appear to be a limit to the number of aircraft flying at any one time ; already many authoritative persons are complaining that air space is becoming dangerously cramped.

Aircraft are very expensive and a freighter to our requirements would cost £800,000 or more, therefore the £4,500,000 for our full fleet of road vehicles would purchase only five and a half aircraft. It would then be necessary to build or purchase or hire airfields, &c., which would make the practical economics quite impossible in relation to the annual tonnages necessary.

Helicopters to date are capable of lifting 3 to 5 tons at the most, possibly they will in future lift greater loads, however, the huge initial cost and other factors make them quite impracticable for our use for a long time to come.

V.T.O. aircraft are still experimental and an unknown quantity, and much research and development will be necessary before they can be considered.

On the whole it can be said that the aircraft is ideal for passenger services, and for light loads of express freight, but quite out of the question when we consider the loads we desire to carry and the economics involved.

Why not build ships ? As we have observed, the ship is limited by its inability to leave the water—its operating medium—and therefore creates economic difficulties reflected upon the retail price of the goods which it carries. Doubtless, for minerals, heavy loads of goods classified as indivisible loads, especially where loading and unloading can be mechanical, as with coal, wheat and oil, it will continue to give good service.

A ship to carry 5000 tons will cost to-day about £1,000,000 ; for this we could construct twenty complete road trains, which are far more flexible than the ship, have little maintenance and far fewer in their crews, whilst the loss of one such vehicle would cost little in proportion to the whole. One

ship, whether lost, seriously damaged or laid up would cost considerably more.

Naturally, ships will always be required, but not in such large numbers as in the past, for, as more countries develop efficient roads fewer ships for coastal work will be required.

There does not appear an alternative to the road-vehicle train.

Distant Future

As road transport engineers we think in terms of road vehicles ; and as the railwaymen familiar with the steam locomotive refused at first to accept diesel and electric traction for fear of losing their old love, we too must be careful to guard against a similar error and be open minded enough to accept change.

It is possible that many of the cargoes now carried by vessels and vehicles will be pumped by pipeline from city to city, and country to country, under the surface of the land and sea, and handling costs would thus be greatly reduced. Coal, either as dust or in water, flour, wheat and cement, in fact almost any product or raw material required in large quantities, can be mixed with air or water and pumped through pipes.

There is no need for a multiplicity of pipelines, as a layer of air can easily be pumped between each of these through a single pipe, and if adequate cleaning is carried out at the discharge point nothing will suffer.

As an example, at a large control point, suitably geographically situated, a quantity of all types of commodity may be sent to many cities by a single pipeline. The operator at each city may order by telephone whatever may be required and these would be sent through the pipe. As there will be a time factor and the air pocket between items being conveyed can be made to any required length, obviously the operator has only to wait until his requirements are at a certain point and then switch these through another pipeline for storage, cleaning or processing.

Such an arrangement, although expensive to install, would require very low maintenance and give long life.

Many countries now extremely backward may eventually, by this system, become rapidly up to date, as much money would be saved, for main roads could be made smaller and cheaper, which applies also to bridges and tunnels.

In a very desolate area, such as parts of Asia, a nuclear power station near the sea could supply adequate air and electricity for such a scheme, and the use of radio for communication between vehicles could ensure safety and efficiency.

The wheel, for so long considered vitally important, will perhaps become an historical museum piece.

Conclusion

At present we are living in a world which would appear to be suffering a great sickness, from muddled thinking, both in political and technological thought, and more so in its practical applications. Thus it may be that we are witnessing a condition similar to that of people who lived in the early nineteenth century. They did see and assist in the change from muscle power to machine power, in fact, within the United Kingdom was born mechanical engineering.

A third great war is about to break forth ; not of the shooting kind, for thanks to science and its development we have, we hope, been granted wisdom and tolerance, even if this be only through fear. This third war is to be an economic one—the ability to force upon the adversary one's ideology by betterment—and we shall always have to be ready to face competitive counter attacks.

All this will bring great improvements, many of which will be in transportation. As the growth of railways and shipping brought improvement to the standard of living, so also will road transport, especially to those areas of Eastern Europe and Central Asia where there is so much which has to be done.

The betterment of conditions means more trade; however, we must ensure that our ability to lead by example does not fail ; by making the necessary effort we will help ourselves equally with others. We must offer and give a service, and how better than by becoming the road transport contractors to Europe and Asia.

The Channel Tunnel Report

The Channel Tunnel Study Group has now published its report on the extensive investigations which it has made into the project for a channel crossing. Some of the principal technical considerations have been abstracted from the report in the following paragraphs. The project for a channel bridge is referred to only in economic comparison, for it was described quite fully in our issue of April 8 last, page 607. The Group's conclusion is that a rail tunnel should be built, at an estimated first cost of £109 million. There is no clear advantage between "bored" or "immersed" designs, but certain proposals giving governmental safeguards to the privately-raised capital sums are suggested in the full report.

THE Channel Tunnel Study Group was set up on July 26, 1957, on the initiative of the Compagnie Universelle du Canal Maritime de Suez, with which were associated on an equal footing the two companies, English and French, which had sponsored past studies and the newly-created American company, Technical Studies Inc. The aim of the Group has been "to carry out joint studies of the conditions in which it would be possible to build and operate a submarine tunnel for rail and/or road traffic, connecting British territory with that of Continental Europe."

The Study Group comprises : (1) The Channel Tunnel Company, Ltd., in which the British Transport Commission is a shareholder, and other associates constituting the British Group. (2) The Société Concessionnaire du Chemin de Fer Sous-Marin Entre la France et l'Angleterre, in which the Société Nationale des Chemins de Fer is the main shareholder, which with its associate The International Road Federation (Paris office) constitutes the French Group. (3) The Compagnie Financière de Suez. (4) Technical Studies Incorporated of New York.

M. René Malcor was entrusted with the task of directing the technical studies. He was assisted on the British side by Mr. H. J. B. Harding. The work of the Group has included the following studies :

(*a*) A traffic survey, carried out by specialist organisations in Britain, France and the United States with the assistance of experts of the British and French Railways.

(*b*) A geological study by British, French and American consulting geologists.

(*c*) A technical study in civil engineering, carried out with the collaboration of British, French and American firms of consulting engineers.

(*d*) A financial study, carried out with the collaboration of banking establishments in the three countries.

(*e*) A legal study, dealing with the creation and corporate form of the organisation charged with building and operating the Tunnel.

Design for a Bored Tunnel

The civil engineering study for a bored tunnel for both rail and road was entrusted to two groups of consulting engineers. In London : Sir William Halcrow and Partners, Messrs. Livesey and Henderson, Messrs. Rendel, Palmer and Tritton ; in Paris : Société Générale d'Exploitations Industrielles (SOGIE). The bored tunnel might consist of a railway tunnel and/or a road tunnel, separate but adjacent, keeping within the lower part of the Lower Chalk. It would cross the Straits between Dover and Sangatte.

Railway Tunnel.—For this type of construction, ventilation does not give rise to any serious problems, and its effect on the cost would be negligible. The terminal railway stations would be sited between Ashford and Folkestone in England and near Calais in France. They would be about 44 miles apart by the tunnel. The tunnel proper would be 32 miles long between portals. The part under the sea, slightly inclined to follow the Lower Chalk, would be 23 miles long. The English land tunnel (7 miles) and the open approach to the terminal (9 miles) would be longer than on the French side (3 and 1¼ miles respectively) because of the need to emerge behind the cliffs and to reach an area suitable for terminal installations. The conditions behind Sangatte and Calais, for the French entrance, are more favourable.

The construction would consist of two parallel one-way tunnels of 21ft 4in internal diameter, with cross passages and four cross-over junctions. A service tunnel of 10ft 10in internal diameter would be driven a certain distance ahead of the main tunnels, between and slightly below them. It would be valuable for construction work, maintenance and drainage.

The longitudinal section of this system of tunnels would be in the form of a "W" with the high point on the French side of the centre of the Channel, at about 125ft below the bed of the sea which is here 148ft deep. Two drainage galleries will drain off water from the low points of the "W" towards each coast.

The concrete lining of the main tunnels will be 15in thick, and that of the service and drainage galleries will be 6in to 9in. The permanent way would be on ballast above a drainage channel. The gradients in general would not exceed 10 per 1000 (exceptionally 11·6 per 1000). The curves would have a radius of not less than 3937ft (exceptionally 3445ft).

Traction would be entirely electric with current at 25,000V. The catenaries, hung from the roof of the tunnel, would be parallel, leaving a clearance of 14ft 11in above the track. The lines for the cross-channel shuttle service would have a loop at each end so that trains do not have to reverse to return from one station to the other.

The terminal installations have been carefully designed to speed up the operations of loading and unloading vehicles. The rail

tracks would be flanked by platforms 46ft 9in wide. Some would be at a high level for loading double-decker wagons. The buildings, parking spaces and traffic control have all been studied. In addition the stations would have easy connections with the rail and road systems, both in France and Great Britain.

The estimated cost of a railway tunnel is as follows :

	£ million
Engineering work	80·0
Railway installations between terminals	9·8
Terminal stations	14·0*
Rolling stock	6·0
	109·8

* This figure represents the estimated cost of the initial installations necessary when the tunnel first comes into operation. It would have to be increased to £17,000,000 by 1980.

In addition it is estimated that improvements to the French road system serving the terminal would cost £2,200,000, which would bring the total cost up to £112 million.

Maintenance and renewal expenses would be as follows :

	1965	1980
	£	£
Railway installations	1,050,000	1,050,000
Tunnel proper	253,000	480,000
	1,303,000	1,530,000

Construction work is expected to take five years.

Road Tunnel.—The terminals for the road tunnel have been planned at about 1 mile behind Sangatte and 2½ miles inland from Dover, at points where the simplest connections can be made to the highway system. The total distance between terminal stations would be 26 miles, of which 23 miles would be below the sea.

The complete construction would consist of two circular tunnels of 36ft internal diameter, each with a roadway 29ft 6in wide. As it appears reasonable to consider constructing them in two successive stages, preliminary plans have concentrated on a single two-way road tunnel. The 29ft 6in roadway would run between kerbs with a raised footway on one side and would allow for one traffic lane 11ft wide in each direction, with a central lane 8ft wide for stationary vehicles.

A second variation has been studied with a roadway 32ft wide with two 11ft traffic lanes and a 10ft wide parking space in the centre. The internal diameter of this tunnel would be 39ft 4in.

Assuming that a railway tunnel has already been constructed alongside, cross passages would make it possible to use the railway service tunnel for constructional and maintenance purposes. The road tunnel would also be in the form of a " W " with gradients of not more than 4 per cent and curves of not less than 3280ft radius. The concrete lining would be 33½in thick for the road tunnel, as compared with 30in for the rail tunnel.

The ventilation of so long a road tunnel presents serious problems, which have been studied for both plans. In order to meet accepted standards and to avoid concentrations of carbon monoxide greater than 2 parts per 10,000 at peak traffic of 750 vehicles per hour, the following installations are envisaged. A " transversal " system would be used, fresh air being introduced and foul air drawn out laterally all along the tunnel. Fresh air would be drawn in from each end of the tunnel and also from intermediate shafts on one or two artificial islands according to the alternative chosen.

As the first alternative tunnel would have an internal diameter of 36ft, one artificial island would be required. Fresh air would be drawn in through the railway tunnels and through cross passages joining them to the road tunnel. The air would enter at road level on one side only. The foul air would be sucked out through openings on the opposite side of the roadway and discharged through ducts in the spaces above and below the roadway. This system would require an installation of 146 fans and a total power of 24,000 h.p.

The second alternative tunnel would have an internal diameter of 39ft 4in, and would be supplied by two intermediate air shafts on two artificial islands. In this case the fresh air would be pumped in through the lower space in the tunnel and introduced at road level on either side of the tunnel. The foul air would be sucked out at the ceiling and expelled through the upper space between the ceiling and tunnel crown. Near the shafts, however, some of the foul air would need to be expelled through the tunnel itself. This installation would require eighteen fans and a total of 7000 h.p. This second alternative would allow twice as much peak traffic (1500 vehicles per hour), though in that case thirty-six fans and 56,000 h.p. would be required.

The cost of the road tunnel has been estimated as follows :

	First alternative 36ft diameter, one island £ million	Second alternative 39ft 4in diameter, two islands £ million
Tunnel proper	104	121
Ventilation plant and islands	17	24
Surface installations†	4	4
	125	149
In addition the French road system would have to be altered to connect with the tunnel at a cost of £3·6 million, making the sum total	129	152

† Note that this figure does not include the necessary installations for transferring rail passengers into motor coaches for the tunnel crossing.

The cost of maintenance has been estimated at £253,000 for the year 1965. The construction is expected to take five years.

Scheme for an Immersed Tube

The study for the above was entrusted to Messrs. Parsons, Brinckerhoff, Quade and Douglas, of New York, who also studied plans for a bridge or a composite bridge and tube. Among the various routes considered, the one preferred was from the French coast near Wissant, crossing the Channel in a straight line and then, after reaching the English coast, curving to emerge at Sugar Loaf Hill between Dover and Folkestone. The total length of this tube between portals would be 29 miles, of which 22 miles would be under the sea.

Three types of construction were considered :

(*a*) An immersed railway tube with two tracks, 45ft 10in external diameter.

(*b*) An immersed road tube of the same size with an internal diameter of 36ft, containing one traffic lane in each direction, with a parking lane between them. As in the case of the bored tunnel, there is an alternative with an internal diameter of 39ft 4in.

(*c*) A combined immersed tube with two railway tracks and a four-way road system on two levels inside a circular tube of 66ft 10in outside diameter.

Ventilation would be provided in the same way as in the bored tunnel, that is to say :

Road Tube.—First alternative : inside diameter 36ft and one artificial island. Second alternative : inside diameter 39ft 4in. Two artificial islands at points one-third along.

Combined Tube.—Two artificial islands.

This immersed tube would consist of units of appropriate length, prefabricated ashore or in floating docks and towed out to the working site. The placing unit would consist of a working platform supported on strong legs above the highest waves. A trench of suitable depth would be dredged by special excavating plant worked from the platform,

The bottom of the trench would be levelled with broken stone stored on the platform. The trench would finally be filled in either with broken stone or with the dredged material, when it can be recovered.

The estimated costs for an immersed tube, submitted by the group of contractors who were responsible for this plan, are as follows :

Rail Tube.—£112·9 million.

Road Tube.—First alternative : £104·2 million ; Second alternative : £114·9 million

Combined Tube.—£201·1 million.

They have estimated that it would take four years to build an immersed rail or road tube, as compared with five years for a tunnel.

Estimated Costs and Revenues

At the first stage at least, the tunnel or tube should carry a railway rather than a road. This conclusion is based mainly on economic and financial considerations.

If a road tunnel was put into service in 1965, its capacity would have to be doubled soon after 1980. At this time, on the other hand, a rail tunnel would have capacity enough to absorb 70 per cent more than the peak traffic estimated—and this calculation is based on 110 trains per day in each direction, while the theoretical capacity would be 216 trains.

As for earning power, the advantages of a rail tunnel are again considerable. The net receipts of a rail tunnel have been estimated as £13,000,000 in 1965 and £21,000,000 in 1980, while the net receipts of a road tunnel would not be more than £9,000,000 in 1965 and £15,000,000 in 1980, or about 73 per cent of the estimated receipts from a rail tunnel. It should again be emphasised that these figures assume a substantial diversion of traffic from the sea-borne service to the coach service between the British and French terminals—a diversion which the railways would have no interest in promoting.

Lower receipts, together with limited capacity, reduce the possibilities of financing a road tunnel by means of private capital, even supposing that the cost of the two types of tunnel was approximately the same.

In fact, if traditional methods of construction are employed, the investment needed for a rail tunnel would be less than that required for a road tunnel. Thus the cost of a rail tunnel, fully equipped together with terminal stations and road approaches, has been estimated at £109 million of which £2,900,000, consisting of enlargements to the terminal stations, need not be spent until around 1980. For the road tunnel, the corresponding estimate is £129 million or £152 million according to whether it included one or two artificial islands. These figures do not include special arrangements for transferring passengers between train and coach.

If the plan for an immersed tube is adopted, the cost is estimated at £112·9 million for a railway and £104·2 million for a road with one artificial island or £114·9 million with two artificial islands. These figures appear to give a slight advantage to a road tube with one island as compared with a rail tube, but this advantage is not enough to compensate for adverse factors as regards capacity and earning power.

A bridge would cost £181 million and a tube for rail and road combined £201·1 million. As these would not give rise to any higher receipts, private financing would be out of the question.

LETTERS AND LITERATURE

Letters to the Editor

We do not hold ourselves responsible for the opinions of our correspondents)

SIMPLIFIED ANTI-VIBRATION HAMMER FOUNDATIONS

SIR,—I have read with interest the article by Dr. Eastwood in your issue of February 26 on Hammer Foundations. His calculations, as far as they go, are accurate, but are so grossly over simplified that they will produce a foundation two to three times more expensive to the client than the more advanced methods now in use. His calculated example gives 0·008in amplitude of ground movement, and is the same as some small hammers make on traditional foundations ! An "anti-vibration foundation" must reduce the ground vibration very substantially more than this, and the best specialists in this field, using advanced methods, are obtaining ground movements from five to twenty times less from much bigger hammers !

I have continually written and lectured to emphasise that the Degebo published figures for natural ground vibration frequencies must never be used in practice but always measured afresh on each site. Apparently he ignores these frequencies and recommends others to do the same. He compares sound waves in the open air with those in the ground for the purpose of showing that the ground can have no natural frequency, but since airborne sound consists of "P" or pressure waves only, the comparison cannot be made. Site or ground natural frequency phenomenon is closely associated with the much larger Raleigh wave which cannot occur at all in air. Eastwood denies that this so-called soil frequency exists, but I do not agree with him, having taken some thousands of vibration tests on hundreds of sites and carried out years of research, some of which have not yet been published.

He says it is impossible to calculate the natural frequency of a proposed foundation, but again I do not agree with him ; I have always been able to do so successfully. For hammers I measure the site frequency first, using impact methods—not Degebo oscillator methods. In practice the weight of the volume of soil excavated very nearly equals the weight of the foundation materials replacing it (i.e. concrete, machine, airspace) so that the *status quo* in the soil is usually largely regained when the foundation is completed. Mainly for this reason the natural frequency of the original site is only a little changed in the new installation. This has occurred in hundreds of jobs. Obviously sometimes there are complications, but in my view these are not sufficient reasons to decry the existence of this little understood phenomenon.

I have certainly no misconception as claimed by Eastwood on the principle that, if the natural frequency of the sprung foundation and that of the outer concrete and ground are identical, a state of resonance will exist. This is a physical fact. In my opinion the misconception is when it is suggested that it is the hammer which is most affected practically. After the initial shock has set the ground and outer foundation oscillating at its own natural frequency the sprung foundation block (unless heavily damped) executes several cycles of oscillation at its own particular natural frequency. The resulting oscillatory loading to the ground and outer foundation forces them into oscillation at this same frequency. If this frequency is identical with that of the natural frequency of the ground and outer foundations of the installation, then a resonant build up of amplitude in the ground will ensue, with consequent increase in the disturbances (or Raleigh waves) in the neighbourhood. Eastwood's simplified method completely ignores this. The primary function of the anti-vibration hammer foundations is to reduce these waves, but resonance with the ground increases them. However, such resonance affects the actual hammer itself very little and the stamper and other operatives hardly notice anything different. The increase in ground waves, though, can be immense and even amount to a public nuisance actionable under several Acts.

Eastwood also infers that several different kinds of hammers on one site all produce different soil vibration frequencies. In my opinion this is utterly wrong for any low frequency site, where the short shock and the higher anvil frequencies must induce the lower site frequency into dominant action. If instrumental readings are taken on such a site, the point is easy to demonstrate.

Eastwood attacks the simplified caption to a diagrammatic illustration of the Lockheed hammer foundation damper, extracted from a non-technical article of mine. He says that dampers are required to have free downward movement, with heavy damping on the upstroke ; Lockheed dampers do exactly this, and I am gratified that my foresight in working out these dampers fifteen years ago was fully justified. They were Ministry sponsored and have been in use in industry for ten years.

I do not agree with Eastwood when he says that a hammer foundation can only oscillate in three out of the six degrees of freedom. All practical forge men know this ; there is much unbalanced and twisted forging of propellers, crank shafts, couplings, connecting rods, saucepan handles, spanners, &c. in dies, and for open forging there is shouldering, cutting, hogging, &c., all of which induce important off-centre effects. Eastwood assumes that the eccentricity of a blow is too small to worry about its effect, but I have measured 2ft 6in and seen more. All forge men know they are very important. In practice the rotational mode induced in a spring foundation block by an eccentric blow is initiated together with the translational mode also—they are inevitably "coupled." Eastwood believes they are separate, This is physically not possible for a hammer foundation. In my opinion a practical application of Eastwood's thesis can only lead to undesirable increase in maintenance of the hammer itself by allowing greater accelerations and movements in "sway" than is advisable.

The more advanced methods now in use have been devised by several teams in different parts of the world to cover the practical cases in industry. To my knowledge in Great Britain, Germany and the U.S.A. about 1500 sprung hammer foundations have been built. Simplified methods were once in use, but have had to be superseded by more accurate conceptions to produce both cheaper and more reliable jobs.

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Carshalton,
Surrey,
April 13, 1960.

RAILWAY CONVERSION

SIR,—You included in your leading article on March 18 a final aside about my wanting to convert the railways into roads. It will have given newcomers to the subject a very false idea of this five-year controversy ; however, the point I wish to pursue concerns your use of the word "roads."

The railways will convert into something for which the word "roads" is inadequate. "Motorways" has unfortunately been appropriated for extravaganzas like M.1 ; though it is to be noted that, possibly owing to a Swiss preference for the single carriageway, the international definition does not specify dual carriageways. "Clearways" has been adopted by the Ministry of Transport for public highways cleared of parked vehicles but still obstructed by mixed traffic and frequent one-level intersections.

Some other distinctive word is required for the roads the railways can become. Their chief characteristics will be free flow, controlled access and negligible gradients. Free flow alone suffices to set motorways in a class apart ; the converted railways will be in a yet higher class, having special merits, of which I would mention two in particular.

The first concerns capacity. It is axiomatic that free flow confers on a road many times the capacity of a public highway of the same width. But I suggest that the chief importance of high capacity is not that the road can carry so many thousand vehicles per hour (which is seldom necessary); it is that one's ease and pleasure in driving are directly proportional to the spare capacity of the road at the time. A flow that would choke a highway may tax the capacity of a free-flow road so little that each driver feels he has the road almost to himself. It is safe to predict that that very desirable state of affairs will be fairly general on the converted railways, not only because of access control, but also because of the extensive duplication of Britain's main railway routes. Each route has to serve only a narrow area ; it will be a great merit of the converted railways that there will be

plenty of them—and accordingly plenty of room on them.

Their other merit I would touch upon, not mentioned in your 1958 correspondence, concerns passenger fares. Long-distance bus fares are already well below rail fares despite the difficulties of operating on a defective, congested highway system. Transfer those same services, though with specially designed buses, on to the free-flow, hill-free converted railways and their profitability must rise astronomically—or fares fall, or both.

For instance, it would be commonplace for a bus to cover 1200 miles a day on any day-and-night service between London and some other large city—say, 400,000 miles a year. If it were a sixty-seater, with average loading forty passengers, its annual takings at the customary fare of 1½d. per passenger-mile would be £100,000 ! Costs could hardly amount to one-seventh of that sum even if the bus were thrown away at the end of the year. Indeed it is safe to predict costs no higher than ¼d. per passenger-mile on such services on the converted railways. Possibly the costs would be double on the short-distance and commuter services, but even so a standard fare of 1d. a mile would enable more than half of the gross bus takings to be classed as profit available for division between the bus shareholders and the Exchequer.

So railway conversion promises fares no higher than 1d. a mile. Meanwhile British Railways are edging their fares up towards their admitted target of 3d. a mile. To charge so much for the trivial service of conveying the human body horizontally (second class into the bargain !) should be recognised as a scandal ; the foot-pounds of work performed on a body in the process represent an amount of energy that can be delivered right into one's home, in the form of electricity, at less than one-thousandth the price !

However, we are no nearer a name for the converted railways. Their merits—of which I have instanced only two—seem too multitudinous, and too diverse, ever to point to any particular name : but I do suggest that it is misleading to give converted railways the bare name of roads : at very least it should be motor roads.

T. I. LLOYD

Guildford,
April 25, 1960.

PEAK LOAD GAS TURBINES WITH AIR STORAGE

SIR,—The several points made by Professor Kapp in his commentary in your issue of April 15 are sound. The cavern cost does, of course, vary more or less directly with the hours of use at full load. We did not think this worth drawing attention to since it was obvious from the method of deriving the itemised cost quoted. There would be a strong case for reducing the available hours of use at full load below four per day in the case of an excavated cavern because of its higher price per cubic foot. However, a difficulty arises in attempting to legislate for the most advantageous use of the plant in that an air storage station as last comer will find time-expired steam stations, pumped storage plants, diesels, and even straight gas turbines already occupying positions near the peak of the load duration curve. Since for one reason or another none of these may be suited to shifting further down into longer hour service, the air storage plant may well have to take on that duty. Since we have shown by quoting factual price data for the main items that such plant is able to compete with pumped storage on the basis of four hours per day generation, the case must clearly be better for shorter hour service where this is acceptable.

Professor Kapp also points out that the air storage plant does not need a mountain. We have indeed always thought of the normal site as being in flat country with underground caverns reached by shaft sinking. The salt cavern site near North Tees Power Station already taken over by the Northern Gas Board was an ideal one since it would have required no reservoir though continued use of fresh water would no doubt extend the salt cavern possibly undesirably.

The practical reason quoted for the use of an after-cooler takes precedence over any economic ones. The economic gain mentioned by Professor Kapp is incidental, but it is not quite all gain since the efficiency would be significantly improved if the air could be stored at compression temperature. However, this is not possible under a water seal. On the other hand the water seal method is shown to have very great economic advantage over dry storage and therefore the after-cooler is correctly described as a necessity.

B. WOOD

Esher,
Surrey,
April 22, 1960.

Book Reviews

Applied Petroleum Reservoir Engineering. By B. C. CRAFT and M. F. HAWKINS. Constable and Co., Ltd., 10, Orange Street, London, W.C.2. Price 62s. 6d.

FOR many years the world annual production of crude oil has approximately doubled every ten years. This increase has been achieved largely by the discovery of new oil accumulations. However, the search for new fields is becoming more and more costly, and more efficient extraction of oil from the reservoirs must be looked upon as an important means for making more oil available at reasonable costs. To those not acquainted with oil fields the comparatively small proportion of the oil content which has been recovered from many fields may be a surprise. The more effective application of sound petroleum reservoir engineering and new developments in this subject will be of prime importance in ensuring higher oil recoveries.

Some of the ideas and methods described in *Applied Petroleum Reservoir Engineering* were employed in a simple form many years ago. The more formal development of petroleum reservoir engineering has, however, taken place during the past quarter of a century. Laboratory and field experiments and studies, as well as mathematical investigations have all contributed to its growth. This is a realm in which the physicist, physical chemist, geologist, engineer and mathematician can apply their skills, and the application is done most successfully when there is full awareness of the nature and setting of an oil or gas accumulation. Two- and three-fluid flow through porous media can involve difficult yet fascinating problems when the pressure can be high, the temperature moderately high, the fluids miscible and immiscible, and the porous medium not necessarily homogeneous as regards its porous structure.

Craft and Hawkins have adopted an unusual arrangement in not discussing Darcy's law, relative permeability and some other points before the last half of the book ; the first half is given over to dealing with oil and gas accumulations as a whole. Estimation of reserves, producing mechanisms and the prediction of the behaviour of hydrocarbon accumulations rightly receive much attention. Gas reservoirs, gas-condensate reservoirs, undersaturated oil reservoirs, and oil reservoirs under simultaneous dissolved gas, gas cap, and water drives are dealt with in succession. In a number of instances specific fields are used to illustrate particular points. Attention is drawn to the shortcomings of some of the data commonly available and to the limitations of some of the methods. Chapters on water influx, fluid flow in reservoirs and the displacement of oil and gas complete the book.

About thirty numerical examples are worked in the text. No doubt many will find these helpful in driving home the use of the various relationships developed. Nearly 200 problems (with answers, where numbers are involved) are given at the ends of the chapters. The illustrations are well drawn and generally clear. However, the absence of a north point and, more important, of a scale and units on the diagrams of the East Texas basin, which has been turned through about 90 deg. from the conventional orientation, will annoy some, and the rather fancy arrows on another diagram may temporarily puzzle others. There is a satisfactory spread of references. A number of the papers dealing with fundamental points, with which a student should become acquainted at an early stage, are listed at the end of the chapter on gas reservoirs, after having received brief mention under the history of reservoir engineering. This may not be the best place for drawing due attention to the papers, so far as some students are concerned.

The authors note that *Applied Petroleum Reservoir Engineering* is primarily concerned with the " application of reservoir engineering data to the calculation of reservoir contents and recovery potentials and to the analysis and prediction of reservoir performance under a variety of production methods . . . The source, nature, and precision of the data upon which the calculations and analyses are based are discussed subordinately." Within these limits the book provides a sound introduction to the subject, and an indication of some of the newer developments. It is a useful addition to the small number of books on petroleum reservoir engineering, differing considerably in composition and emphasis from previous books. The price seems very reasonable by present standards for books of this type.

Electronic Computers—Principles and Applications. (Second Edition). By T. E. IVALL. Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 25s.

THE first edition of this book included chapters by several different contributors. The present edition has been rewritten to provide greater continuity and to include additional material on analogue computing circuits, digital programming and new techniques. There are chapters covering the historical development, construction, and use of both analogue and digital computers.

LETTERS AND LITERATURE *(Continued)*

It is obvious that such a wide field can be covered only at a fairly elementary level in a single book, and the author does describe it as an introduction for beginners. Few publications of this kind succeed in maintaining a steady course between the extremes of excessive detail and vague generalisation. This book is no exception, although it has steered a steadier course than many another. An example of the unbalance is an unexplained reference to optimum programming in a couple of lines, whilst detailed circuits of diode function generators occupy well over a page.

A considerable number of illustrations are included, the majority of which show the arrays of racks, cabinets, consoles and desks which house a variety of British and foreign computers. They give the potential purchaser of a computer some idea of the diversity of size of computers, which will help in dissipating any remnants of the "giant brain" approach to the subject. There are also illustrations of units such as magnetic core stores and magnetic drums. Plate 5 (c) of a mechanical analogue computer seems out of place in a book on electronic computers.

The necessity to generalise has produced some statements that the computer specialist might regard with suspicion. On page 141, one of the advantages of ferro-resonant circuits is stated to be low power consumption, which the designer of modern transistor machines would no doubt deny. The classification of an ordinary magnetic tape system as dynamic storage is not consistent with standard use of the term. The implication that plug-in circuit packages allow a fault to be cleared in the time taken to put in a new package is a gross over-simplification of the problem of repair and maintenance of a large machine. Finally, page 163 gives a wrong impression of the ratio between the number of machines using servo-controlled magnetic drums and those using free running drums.

However, this book can be recommended as a primer for beginners, despite the minor shortcomings. It is readable and up to date. A useful addition to the next edition would be a selected list of references for further reading.

Marine Lubrication. By G. H. CLARK. Scientific Publications (Great Britain), Ltd., Broseley, Shropshire. Price 100s.

THIS is a monumental work consisting of forty-nine chapters, and is really a combined book on "Marine Machinery and Lubrication." There are many chapters which do not deal with lubrication at all. For example, Chapter VIII is devoted to the fuel consumption and thermal efficiency of various types of marine machinery; Chapter XVI deals with modern gear designs; Chapter XXI, scavenging and pressure charging of diesel engines; Chapter XXIII, fuels used in marine diesel engines; Chapter XXXIV, free piston gas generators; Chapter XXXV, marine gas turbines; Chapter XXXVI, elements of nuclear technology, and, strangest of all, Chapter XLII on modern marine boilers and associated machinery (where absence of lubrication is specially important). It is agreed that all these chapters added to the lubrication of marine machinery do make a complete text book on all aspects of machinery likely to be found at sea, including the chapters on nuclear propulsion of ships.

The lubrication parts of the book are excellent, providing it is understood that the subjects are all dealt with in a general and practical fashion without the use of advanced mathematics. The chapters on steam turbine lubrication systems are particularly good. References to further reading are given at the end of each chapter, which is a very useful feature of the book. Even accepting the remarks in the early part of this review, which are intended to give an idea of the broad field covered by the author, it will be found that this is a very useful book for the practical man engaged in the construction or running of all types of marine machinery. The evaluation of the main factors affecting the lubrication of parts which so greatly contribute to the running and life of machinery, is very well done.

The author quotes extensively from many papers on marine engineering but does not modify them as a result of his own experience or knowledge. For example, at the end of Chapter XXXVI, "Elements of Nuclear Technology," he states that sea water contains 1 part in 6000 of heavy water from which deuterium can be obtained, and it has been estimated that 1 gallon of water could provide as much energy as several million gallons of petrol. The first part of the statement is reasonably correct, although it should be a ratio of hydrogen to deuterium and not heavy water to light water, but the heat equivalent in each gallon of sea water providing the deuterium can be used is not equal in energy to several million gallons of petrol but between 39 to 165 gallons of petrol, depending on the particular fusion reaction which might take place.

Festschrift für Richard Grammel. Zum 70. Geburtstag am 3. März, 1959. Edited by K. v. SANDEN, with the co-operation of A. Betz, H. Görtler, K. Klotter, K. Marguerre and E. Mettler. *Ingenieur-Archiv*, Vol. 28, 1959, Berlin-Göttingen-Heidelberg: Springer-Verlag, Berlin-Wilmersdorf, Heidelberger Platz 3. Price DM.52.

THE present volume of *Ingenieur-Archiv*, the well-known journal of applied mathematics, marks the seventieth birthday of Professor Richard Grammel who, in 1929, founded this publication and remained its editor-in-chief for thirty years. From its beginning it has been the aim of the *Ingenieur-Archiv* to foster the relations between scientific research and technical practice. To the approximately 1000 papers which bear witness over the years to the success of this policy, there are now added a further forty-five research reports on a wide variety of subjects contributed by students and friends of Professor Grammel.

Books Received

Aluminium Busbar. By A. G. Thomas and P. J. H. Rata. Hutchinson and Co. (Publishers), Ltd., 178-202, Great Portland Street, London, W.1. Price 21s.

Neuzeitlicher Strassenbau Aufgaben und Technik. By F. Neumann. Springer-Verlag, Berlin-Wilmersdorf, Heidelberger Platz 3, Western Germany. Price DM.66.

Windscale—Problems of Civil Construction and Maintenance. By Stuart Sinclair. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2. Price 25s.

Handbook of Heating, Ventilating and Air Conditioning. Fourth Edition. By John Porges. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2. Price 30s.

Technical Reports

Modern Explosives. By the late Wilfrid Taylor, M.Sc., Ph.D. The Royal Institute of Chemistry, 30, Russell Square, London, W.C.1. Price 6s.—This monograph was practically completed by Dr. Taylor when he died in 1958 and was finished by some of his colleagues in the Nobel Division of Imperial Chemical Industries, of which he was the Joint Deputy Research Manager. Few authorities on the subject of explosives could have been better qualified to write this monograph, for Dr. Taylor spent most of his working life dealing with explosives and allied subjects and had a world-wide reputation. In this publication there has been condensed a vast amount of information which is presented in a clear, concise way to provide a comprehensive review and a guide which will be of value to students. The subject matter has been arranged under ten main headings: explosion and detonation, explosive characteristics; intrinsically explosive substances, evolution of commercial explosives, physical phenomena of detonation, physical action of explosives, hydrodynamic theory of detonation, reaction mechanisms, coal mining explosives, and special applications of explosives; concluding with a useful appendix giving formulæ of common explosive compounds.

Timber Roofs for Factory Buildings and the Thermal Insulation (Industrial Buildings) Act, 1957. Timber Development Association, 21, College Hill, London, E.C.4. Price free.—The stress laid in the 1957 Act and in the Regulations formulated by the Minister of Power on the need to avoid undue fire risk in complying with the insulation requirements makes it essential, in the T.D.A.'s view, to stress several points in connection with timber construction. First, that the restrictions with regard to the use of certain materials (including timber) apply to their use as insulating materials and not their use for structural or other purposes. Timber in the framework of the roof is therefore unaffected by the Act. Secondly, there are many ways in which timber can be used in roof construction, both singly and in combination with other materials, to contribute to the standards of insulation acceptable under the Act. Finally, there are numerous methods of treating timber and timber products (e.g. fibreboards), either during manufacture or after erection, which will retard the surface spread of flame of these materials, making their use acceptable under the Act.

The purpose of this booklet is to provide information on these different aspects and offer a variety of constructions to meet the thermal insulation requirements of the new regulations whilst making the best use of timber in other respects. Much of the information is provided in tabular form.

Radio Research, 1958. Department of Scientific and Industrial Research. Published by H.M. Stationery Office. Price 3s. 6d.—The record of work in 1958 by the Radio Research Organisation on studies of the ionosphere and radio transmission includes a section dealing with special investigations for the International Geophysical Year. Arising from these activities, a programme was initiated for the production on a computer of N(h) profiles showing the distribution of electron density with height in the ionosphere. Such profiles can be derived from the ionograms which are produced at ionospheric observatories, but the necessary calculations are very laborious and, unless approximations are used, they can only be carried out economically with an electronic computer. During the I.G.Y. the back-scatter plan position indicator at Slough was operated as part of the year's observation programme, directing particular attention to the study of sporadic E ionisation. This technique has been applied at the Birdlip radio station of the Ministry of Aviation, where it has proved a useful adjunct to the operation of h.f. point-to-point and air-to-ground services. An account is given of the organisation's participation in space research, which has provided a new tool in the form of earth satellites for the study of the ionosphere and wave propagation through it. Research continued on radio wave propagation through the troposphere. This work was extended to cover the effects on u.h.f. telephony with frequency modulation of delayed echoes along the relatively short, unobstructed transmission paths used by microwave links. Construction was begun of a transmitter and receiver using O-type carcinotron backward-wave oscillators capable of being swept over a 500 Mc/s band, in order to examine the variation of signal amplitude with frequency, and arrive at conclusions regarding the maximum frequency bandwidth practicable in services of this kind. The report also describes investigations of semiconductors and ferrites, and refers to the programme of radio measurements of secondary standard calibre up to the highest frequencies now in use.

THE ENGINEER

Technical Contributors Section

APRIL 1960

Heat Exchange in a Self-Jacketed Fluid

By C. D. WEIR

An interesting and unusual application of the theory of heat exchangers occurs in the case where a fluid is losing heat to the surroundings through a jacket provided by itself. This arrangement is sometimes adopted, for example, in flow calorimeters where it is desired to restrict as far as possible the "heat leak" from the measuring section. Fig. 1 illustrates the arrangement diagrammatically for a single-jacket system and Fig. 2 for a two-jacket system. In the case of flow calorimeters, the measuring stations would, of course, be situated in the inmost pass in each case. Though self-jacketing is a not uncommon device, curiously enough the equations governing the temperature distribution in the system, and therefore the heat loss, do not appear to have been given anywhere in the literature. It seems worthwhile, therefore, briefly to present them here. It transpires that in the single-jacket case the problem is essentially similar to the determination of the temperature distribution in a single-pass shell and tube exchanger and to that of heat exchange between three fluids. The former has been treated by Nesselmann[1] and the latter by Morley.[2] Mathematically the problem is also analogous to the treatment of the two tube pass, single shell pass heat exchanger analysed by Underwood.[3] In view of this it will suffice merely to exhibit those features which are peculiar to the problem treated here; namely, the modified coefficients of the equations and the unusual terminal conditions. The solution of the problem in the case of a double jacket is more cumbersome but presents no essentially new features; an approximate solution has, however, been obtained for this case which may be found to have some points of interest.

IT is not the purpose of this short article to present numerical data on heat losses from jacketed systems since these will depend greatly on the physical circumstances obtaining in any particular case. In the analysis the assumptions (see, e.g. Hausen[4]) customary in heat exchanger design have been made, namely, that the overall heat transfer coefficients and specific heats are constant in each section and that the jacket arrangement is long, so that end effects may be ignored. In this connection it should perhaps be emphasised that the relations are intended to serve as a guide in design; so many variables will usually be involved in the practical case that heat losses can only be determined accurately by actual measurement.

Single Jacket

The arrangement is sketched in Fig. 1. The constant temperature of the surroundings is denoted by t_s and the temperature of the fluid at the inlet to the system by t_i. The total effective surface for heat transfer between the jacket (or outer pass A) and the surroundings is F_A and the effective surface from the origin up to some intermediate section is f_A. The temperature of the fluid in the outer pass at f_A is t_A and the corresponding temperature in the inner pass is t_B. If f_B is the effective surface for heat transfer between the inner and outer passes at f_A then we assume, as will normally be the case, that f_B/f_A is a constant a, say. As regards the origin and sign of f_A we adopt the following conventions :

(a) the origin is at the outlet of the inmost pass for inward flow ;

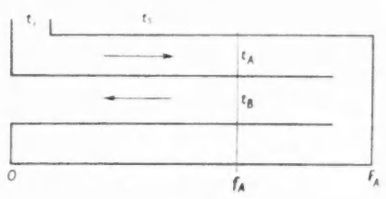

Fig. 1

(b) the direction of f_A positive is the direction of flow in the outmost pass.

Let h_A, h_B be the overall heat transfer coefficients between the outer pass and the surroundings and between the inner and outer passes respectively and C_{PA}, C_{PB} the specific heats ; also let m be the time rate of mass flow.

Introducing the normalised temperatures

$$\theta_A=\frac{t_A-t_s}{t_i-t_s} \quad . \quad (1a) \text{ and } \theta_B=\frac{t_B-t_s}{t_i-t_s} \quad . \quad (1b)$$

and the normalised heat transfer surface

$$\phi=\frac{f_A}{F_A} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

we easily find* from heat balance that

$$-\frac{d\theta_A}{d\phi}=p_A\theta_A-p_B(\theta_A-\theta_B) \quad . \quad . \quad . \quad (3)$$

and

$$\frac{d\theta_B}{d\phi}=p_B(\theta_B-\theta_A) \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where for brevity we have written

$$p_A=\frac{h_AF_A}{mC_{pA}} \quad . \quad (5a) \text{ and } p_B=\frac{h_BF_B}{mC_{pB}}=\frac{ah_BF_A}{mC_{pB}} \quad . \quad (5b)$$

where $a=f_A/f_B$ and is assumed constant. Eliminating in turn θ_B and θ_A from equations (3) and (4) gives the following relations between the normalised temperatures in each pass and the normalised area of heat transfer surface :

$$\frac{d^2\theta_A}{d\phi^2}+p_A\frac{d\theta_A}{d\phi}-p_Ap_B\theta_A=0 \quad . \quad . \quad (6a)$$

$$\frac{d^2\theta_B}{d\phi^2}+p_B\frac{d\theta_B}{d\phi}-p_Ap_B\theta_B=0 \quad . \quad . \quad (6b)$$

in which it will be noted that the corresponding coefficients are identical.

The general solutions are

$$\theta_A=A_1e^{\lambda_1\phi}+A_2e^{\lambda_2\phi}$$

$$\theta_B=B_1e^{\lambda_1\phi}+B_2e^{\lambda_2\phi}$$

where λ_1, λ_2 are the roots of the characteristic equations, i.e.

$$\frac{\lambda_1}{\lambda_2}=-\frac{p_A}{2}\pm\sqrt{\left(\frac{p_A}{2}\right)^2+p_Ap_B} \quad . \quad . \quad (7)$$

The boundary conditions are

$$\theta_A=1 \text{ when } \phi=0$$

$$\theta_A=\theta_B \text{ when } \phi=1 \quad . \quad . \quad . \quad (8)$$

of which the second is peculiar to a self-jacketed system. From equations (8) and by comparison of coefficients on substitut-

* Hausen,[4] page 176 ff.

ing in equations (3) and (4) in the usual way we obtain

$$A_1=-\frac{\frac{\lambda_2}{\lambda_2-p_B}e^{\lambda_2}}{\frac{\lambda_1}{\lambda_1-p_B}e^{\lambda_1}-\frac{\lambda_2}{\lambda_2-p_B}e^{\lambda_2}} \quad . \quad . \quad (9a)$$

$$A_2=-\frac{\frac{\lambda_1}{\lambda_1-p_B}e^{\lambda_1}}{\frac{\lambda_1}{\lambda_1-p_B}e^{\lambda_1}-\frac{\lambda_2}{\lambda_2-p_B}e^{\lambda_2}} \quad . \quad . \quad (9b)$$

$$B_1=-\frac{p_B}{\lambda_1-p_B}A_1 \quad . \quad . \quad . \quad . \quad (10a)$$

$$B_2=-\frac{p_B}{\lambda_2-p_B}A_2 \quad . \quad . \quad . \quad . \quad (10b)$$

This completes the solution of the single-jacket case.

Two Jackets

In this arrangement, which is shown in Fig. 2, there are three passes in all. Denoting the inmost pass by C we have, in analogy with the quantities defined in the previous section,

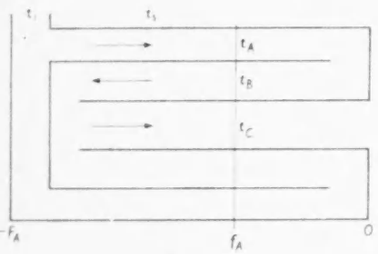

Fig. 2

$$\theta_C=\frac{t_c-t_3}{t_i-t_3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1c)$$

and

$$p_C=\frac{bh_CF_A}{c_{pC}m} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5c)$$

where $b=f_C/f_A$ is a constant. In the relations (2) and (5a) to (5c) F_A is to be taken positive, but in order to comply with the sign convention it is necessary to take the total heat transfer surface between the pass A and the surroundings as $-F_A$, and this is to be borne in mind in inserting the boundary conditions.

Setting up the heat balance equations as before and performing the extremely cumbersome eliminations required the following third order linear equation is found for θ_A :

$$\frac{d^3\theta_A}{d\phi^3}+p_A\frac{d^2\theta_A}{d\phi^2}-(p_Ap_B+p_Bp_C)\frac{d\theta_A}{d\phi}-p_Ap_Bp_C\theta_A=0 \quad . \quad . \quad (11)$$

Analogous relations, with identical coefficients, obtain for θ_B and θ_C. The boundary conditions, which require some care in setting up, are

$$\begin{aligned}&\theta_A=1 \text{ when } \phi=-1\\&\theta_A=\theta_B \text{ when } \phi=0\\&\theta_B=\theta_C \text{ when } \phi=-1 \quad . \quad . \quad (12)\end{aligned}$$

The general solutions of (11), namely

$$\theta_A=A_1'e^{\mu_1\phi}+A_2'e^{\mu_2\phi}+A_3'e^{\mu_3\phi} \quad . \quad (13)$$

and its analogues contain nine constants of which three are determined from the boundary conditions (12) and the remaining six by comparison of coefficients. The exponents of μ_1, μ_2, μ_3 are, as usual, the roots of characteristic equation

$$\mu^3+p_A\mu^2-(p_Ap_B+p_Bp_C)\mu-p_Ap_Bp_C=0 \quad . \quad . \quad . \quad . \quad . \quad (14)$$

and are all real and, in general, different. The further derivations are straightforward but so cumbersome as to be of little practical utility. They will therefore be omitted here in favour of a brief outline of a more useful approximate solution. We shall return to this case in considering a numerical example.

Two-Jacket Case : Approximate Solution

The approximation depends on the physically obvious fact that the influence of the temperature distribution of the third (inmost) pass on the temperature distribution in the first (outmost) pass will be of secondary magnitude and may, to a first approximation, be ignored. This is equivalent to assuming $p_C=0$ in determining the temperature distribution,

$$\theta_A=\theta_A(\phi) \quad . \quad . \quad . \quad . \quad (15)$$

in the first pass. We may then proceed to determine the temperature in the inner pass regarding the temperature distribution in the outer pass as arbitrarily fixed and given by equation (15).

With the same conventions of origin and sign as given previously the differential equation (6a) holds and has the solution

$$\theta_A=A_1''e^{\gamma_1\phi}+A_2''e^{\gamma_2\phi} \quad . \quad . \quad . \quad (16)$$

However the boundary conditions now read

$$\begin{aligned}&\theta_A=1 \text{ when } \phi=-1\\&\theta_A=\theta_B \text{ when } \phi=0 \quad . \quad . \quad . \quad (17)\end{aligned}$$

giving

$$A_1''=\frac{\frac{\lambda_2}{\lambda_2-p_B}}{\frac{\lambda_2}{\lambda_2-p_B}e^{-\lambda_2}-\frac{\lambda_1}{\lambda_1-p_B}e^{-\lambda_1}} \quad . \quad . \quad (18a)$$

$$A_2''=\frac{\frac{\lambda_1}{\lambda_1-p_B}}{\frac{\lambda_2}{\lambda_2-p_B}e^{-\lambda_2}-\frac{\lambda_1}{\lambda_1-p_B}e^{-\lambda_1}} \quad . \quad (18b)$$

If now we take heat balances for the centre and inner passes and carry out the eliminations as before we obtain the following equations for θ_B and θ_C :

$$\frac{d^2\theta_B}{d\phi^2}-p_B\frac{d\theta_B}{d\phi}-p_Bp_C\theta_B=-p_B\frac{d\theta_A(\phi)}{d\phi}-p_Cp_B\theta_A(\phi) \quad . \quad . \quad . \quad . \quad . \quad (19)$$

and

$$\frac{d^2\theta_C}{d\phi^2}-p_B\frac{d\theta_C}{d\phi}-p_Bp_C\theta_C=-p_Bp_C\theta_A(\phi) \quad . \quad . \quad . \quad . \quad . \quad (20)$$

On substituting from (16) we obtain

$$\frac{d^2\theta_B}{d\phi^2}-p_B\frac{d\theta_B}{d\phi}-p_Bp_C\theta_B=-p_B\{A_1''(\lambda_1+p_C)e^{\gamma_1\phi}-A_2''(\lambda_2+p_C)e^{\gamma_2\phi}\} \quad . \quad . \quad . \quad . \quad . \quad (21)$$

and

$$\frac{d^2\theta_C}{d\phi^2}-p_B\frac{d\theta_C}{d\phi}-p_Bp_C\theta_C=-p_Bp_C\left(A_1''e^{\lambda_1\phi}+A_2''e^{\lambda_2\phi}\right) \quad . \quad . \quad . \quad . \quad . \quad (22)$$

A particular integral of (21) is

$$K_1e^{\gamma_1\phi}+K_2e^{\gamma_2\phi}$$

where

$$K_1=-\frac{p_B(\lambda_1+p_C)A_1''}{\lambda_1^2-p_B\lambda_1-p_Bp_C} \quad . \quad . \quad (23a)$$

and

$$K_2=-\frac{p_B(\lambda_2+p_C)}{\lambda_2^2-p_B\lambda_2-p_Bp_C} \quad . \quad . \quad (23b)$$

giving the complete solution of equation (21) in the form

$$\theta_B=B_1''e^{\gamma_1\phi}+B_2''e^{\gamma_2\phi}+K_1e^{\gamma_1\phi}+K_2e^{\lambda_2\phi} \quad . \quad (24)$$

Similarly it is found that

$$\theta_C=C_1''e^{\gamma_1\phi}+C_2''e^{\gamma_2\phi}+L_1e^{\gamma_1\phi}+L_2e^{\lambda_2\phi} \quad . \quad (25)$$

where

$$L_1=\frac{p_Bp_CA_1''}{\lambda_1^2-p_B\lambda_1-p_Bp_C} \quad . \quad . \quad (26a)$$

and

$$L_2=\frac{p_Bp_CA_2''}{\lambda_2^2-p_B\lambda_2-p_Bp_C} \quad . \quad . \quad (26b)$$

In equations (24) and (25) γ_1, γ_2 are the roots of the characteristic equation.

$$\gamma^2-p_B\gamma-p_Bp_C=0 \quad . \quad . \quad (27)$$

and B_1'', B_2'', C_1'', C_2'' are constants to be determined from the boundary conditions, namely

$$\begin{aligned}&\theta_B=\theta_A \text{ when } \phi=0\\&\theta_B=\theta_C \text{ when } \phi=-1 \quad . \quad (28)\end{aligned}$$

and by comparison coefficients. It is found that

$$C_1''=\frac{p_C}{\gamma_1+p_C}B_1'' \quad . \quad . \quad . \quad . \quad (29a)$$

$$C_2''=\frac{p_C}{\gamma_2+p_C}B_2'' \quad . \quad . \quad . \quad . \quad (29b)$$

and

$$B_1''=\frac{(Y(\lambda_1)-X(\gamma_2))A_1''+(Y(\lambda_2)-X(\gamma_2))A_2''}{X(\gamma_1)-X(\gamma_2)} \quad . \quad . \quad . \quad . \quad (30a)$$

$$B_2''=\frac{(Y(\lambda_1)-X(\gamma_1))A_1''+(Y(\lambda_2)-X(\gamma_1))A_2''}{X(\gamma_1)-X(\gamma_2)} \quad . \quad . \quad . \quad . \quad (30b)$$

in which

$$X(\gamma_i)=\frac{\gamma_i}{\gamma_i+p_C}e^{-\gamma_i} \quad . \quad . \quad . \quad . \quad (31a)$$

$$Y(\lambda)=\frac{p_B\lambda}{\lambda^2-p_B\lambda-p_Bp_C}e^{-\lambda} \quad . \quad . \quad (31b)$$

The values of A_1'', A_2'' have already been given in equations (18a) and (18b).

An example of the application of the results presented above is given as an Appendix. Finally, it is worth noting that an interesting application arises in the case of a Joule-Thomson calorimeter where, by the application of a twin-jacket system, it is possible to arrange for the net heat leak to be zero ; the discussion of this application would, however, exceed the scope of this article.

Acknowledgments

Acknowledgments are due to the authorities of the University of Glasgow who provided facilities for the preparation of this paper and to Professor James Small for his interest and encouragement.

APPENDIX

As an example we consider the exact solution of the two-jacket case. We assume $p_A=0{\cdot}6$; $p_B=0{\cdot}4$; $p_C=0{\cdot}2$; these values are of the order which might be expected to arise in a laboratory-scale flow calorimeter for a gas.

Substituting these numerical values in the characteristic equation (14) we obtain by trial and error solution of the cubic

$$\mu_1=+0{\cdot}378 \; ; \quad \mu_2=-0{\cdot}054 \; ; \quad \mu_3=-0{\cdot}923.$$

It is easy to show that the constants B_1 . . , C_1 . . , in the analogues of (13) have the form

$$B_1'=\frac{1}{p_B}(\mu_1+p_A+p_B)A_1'$$

$$B_2'=\frac{1}{p_B}(\mu_2+p_A+p_B)A_2'$$

$$B_3'=\frac{1}{p_B}(\mu_3+p_A+p_B)A_3'$$

and

$$C_1'=\frac{1}{p_B}(\mu_1+p_A+p_B)\frac{p_C}{\mu_1+p_C}A_1'$$

$$C_2'=\frac{1}{p_B}(\mu_2+p_A+p_B)\frac{p_C}{\mu_2+p_C}A_2'$$

$$C_3'=\frac{1}{p_B}(\mu_3+p_A+p_B)\frac{p_C}{\mu_3+p_C}A_3'$$

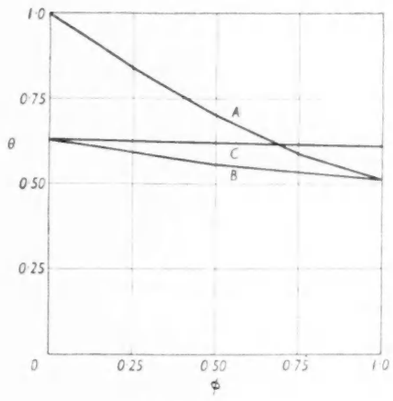

Fig. 3

From which we find

$$B_1' = 2{\cdot}444A_1' \qquad C_1 = 1{\cdot}500A_1'$$
$$B_2' = 1{\cdot}365A_2' \quad \text{and} \quad C_2 = 1{\cdot}500A_2'$$
$$B_3' = -0{\cdot}808A_3' \qquad C_3 = 1{\cdot}500A_3'$$

Introducing the boundary conditions into the general solution (13) for θ_A and its analogues for θ_B and θ_C and substituting the values for the constants we obtain the following set of three linear equations between A_1', A_2', A_3':

$$0{\cdot}686A_1' + 1{\cdot}055A_2' + 2{\cdot}518A_3' = 1$$
$$1{\cdot}444A_1' + 0{\cdot}365A_2' - 1{\cdot}808A_3' = 0$$
$$0{\cdot}648A_1' - 0{\cdot}1425A_2' - 5{\cdot}815A_3' = 0$$

giving finally

$$A_1' = -0{\cdot}488\,; \quad B_1' = -1{\cdot}192\,; \quad C_1' = 0{\cdot}732$$
$$A_2' = +1{\cdot}480\,; \quad B_2' = +2{\cdot}020\,; \quad C_2' = +2{\cdot}220$$
$$A_3' = -0{\cdot}0909\,; \quad B_3' = +0{\cdot}0735\,; \quad C_3' = -0{\cdot}1367$$

The results of the computation are illustrated in Fig. 3. The remarkably small temperature change in the inner section C illustrates convincingly the value of self-jacketing in calorimetric experiments.

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A Critical Look at the Novikov Gear

By HARRY WALKER, D.Sc., M.I.Mech.E.*

The author examines those claims for the Novikov gear which have so far been clearly made, and which are capable of being assessed from existing knowledge. He concludes that, although many of these claims are exaggerated, the Novikov gear could, by suitable development and with modern processes, be made to give up to about double the load capacity of the corresponding involute gearing, and that there is now every reason for practical research on a subject which might prove to be a distinct development in gearing.

AT this early stage in the development of the Novikov gear, I would not presume to make an assessment of its merits, were it not for the fact that I do feel to have a *locus standi* in view of having made and published, some twenty years ago, an incursion into the same subject in the way of an analysis of what at that time I called the "arcuate" gear, and which is now known, in similar basic form, as the Novikov gear. I also think that there are certain misunderstandings, both on the part of those who have written against and for the Novikov gear, and if these are corrected, as they easily can be, it may help to form a clearer view for immediate guidance. There are many debatable questions about the Novikov gear which can only be decided after a long experience, and I propose in the main to discuss only those aspects of the subject on which there is at present sufficient knowledge to make a reasonably accurate judgment.

In the analysis to which I have referred, it was shown that, apart from its outstanding practical advantages, the involute was the worst possible tooth form, from the point of view of load capacity, and that a much better performance could be expected if it were possible to make the lines of contact lie in or near a plane transverse to the gear axes, instead of lying along lines in the general direction of the helix, as occurs in the involute gear. It was then shown that this transverse contact condition could be ideally fulfilled by making the tooth profiles of a pair of helical gears in the transverse section, as circular arcs with coincident centres at the pitch point, as shown in Fig. 1 which is reproduced from the original article.

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It is on this basic principle that the Novikov gear has been designed (with one modification which will be discussed later) and is now being enthusiastically acclaimed and manufactured in Russia.

At the time of my analysis it was not considered that the then existing plant could produce the "arcuate" gear with sufficient accuracy to show up its advantages in practice, and it was not proceeded with.

The first notice of the Novikov gear in this country was in February, 1958, when the *Engineers' Digest* published a technical translation from the Russian. At that time I was not particularly impressed because the technical basis used by the author, A. L. Kaluzhnikov, to compare the load capacity of the Novikov gear with the involute gear

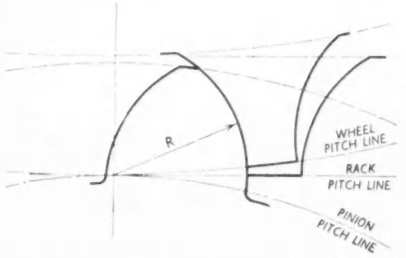

Fig. 1—The basic form of the Novikov gear has circular arc profiles which make instantaneous line contact in the position shown when the centres of the arcs coincide at the point of tangency of the pitch lines. Continuous transmission is obtained by making the gears with helical teeth. In the Novikov development of this form, the radii of the arcs differ by a small amount (as shown in Fig. 4) so that the line contact becomes theoretical point contact. This diagram is reproduced from an analysis which was written by the author twenty years ago

was not correct and tended to favour the Novikov gear to an exaggerated degree. About nine months later, the *Manchester Guardian* published a less technical version which naturally reached a wider general readership and, along with other increasing publicity, caused more interest and comment. A more recent article in the *Guardian* has summed up this comment as "an almost violent reaction and controversy" in this country and a "sceptical and unimpressed" attitude from experts in the States.

Of those comments which I have seen, many of them come from people of long practical experience, who have pointed out that gears with concave convex profiles which could be described as being, at any rate, somewhat similar to the Novikov gear, have been already tried in this country—a perfectly natural thing to say, because although Novikov has undoubtedly contributed something new, he apparently knew nothing of previous work on the same subject, most of which has been carried out in this country and in the States. The commentators have also said that gears with concave convex profiles have not met with such success as would lead one to believe that the Novikov "point contact" feature would alone produce the results now claimed in Russia. My own opinion is that if the case for the Novikov gear had been better presented in the first place, with less possibility of misunderstanding, it would have had a better reception and less opposition.

The final truth of the matter will only be decided by practical test followed by some years of practical application and, even then, much depends on the insight with which reported results are interpreted. There are many examples of new products whose merits or faults, often due to wishful thinking or over-enthusiasm or commercial interest, have remained distorted from reality for many years before falling into a true perspective. The claims from Russian sources for the Novikov gear have, however, already been stated so positively and with such assured finality that it does seem only rational to examine the subject from whatever certain knowledge already exists so as to have as clear an understanding as possible of what might be a major development. It is, therefore, proposed to look more closely into those claims for the Novikov gear which have already been most clearly made and to anticipate how nearly they can hope to be achieved in future practice.

Advantages Claimed for the Novikov Gear

A fair summary of the advantages claimed for the Novikov gear as compared with conventional involute gearing is given below. All these are taken from the references to the Novikov gear listed at the end of this article.

Load Capacity.—An increase in load capacity up to five times that of the corresponding involute gears is claimed. Another statement, presumably a translation, says that Novikov gears are being made "two to two-and-a-half times smaller than the involute ones." If this can be retranslated as meaning that the linear dimensions (i.e. the diameter and face width) of the Novikov gear are rather less than half those of the involute gear, then the relative load capacities of equal-sized gears would be in the region of 6 or 8 to 1, but it is doubtful whether this meaning was intended to be conveyed in the original Russian script. It is also stated that the weight of the Novikov gear is "two to two-and-a-half times smaller than" the weight of corresponding involute gears. This

does not logically agree with the previous statement.

Efficiency.—Power losses in the Novikov gear due to friction are stated to be "from two to two-and-a half times smaller than the corresponding involute gears."

Point Contact.—The feature of point contact, on which much discussion has centred, is described as "a new approach to the principle of meshing." Line contact is described as a "degeneration" of point contact.

Manufacture.—It is stated that Novikov gears can be manufactured on standard gear-cutting machines and have a low sensitivity to machining inaccuracies. One report claims *less* sensitivity to errors in manufacture than the involute.

Running Speeds.—Permissible peripheral speeds are claimed to be "much higher" than those in conventional gearing.

Pitting.—It is said that "Novikov gears have none of the defects of involute gears; one of these defects is pitting."

Cost.—From a statement of how many million roubles are to be saved in Russia during the next few years by using Novikov gears, a claim can be inferred that the combined material and production costs, including smaller gearboxes and larger bearings, are less than for conventional involute gears.

What an impressive list of claims! Hardly one item from a hypothetical list of desirable qualities of the perfect gear would be found omitted from this list.

Adhering to our resolution of examining in detail only those claims which can, at this stage, be reasonably discussed on factual grounds, we can quickly by-pass several of them with the brief (but admittedly speculative) comment below, reserving the major arguments for what are in fact the decisive elements of comparison, namely, relative load capacity (which is bound up with this question of point contact) and relative sensitivity to manufacturing and mounting errors.

Efficiency

This can only be decided by test experience. It is quite likely on theoretical grounds, that equally dimensioned involute and Novikov gears, running at the same peripheral and rotational speeds, would show a higher net efficiency for the Novikov gear. Whether this would be of the order of a change from (say) 99 per cent for a well-made involute gear to 99·5 to 99·6 per cent for an equally well-made Novikov gear, and whether this difference is measurable, are both doubtful. If advantage is taken of the claimed increase in load capacity of the Novikov gear by making it smaller than the involute gear (and it may safely be assumed that no one in their normal senses would dream of making Novikov gears unless they could be made smaller than the involute gears) then the reduction in peripheral velocity for a given rotational speed, would result in a higher coefficient of friction which would tend to counteract the inherent efficiency advantage of the Novikov gear. In any case, the question of efficiency is not of first importance.

Pitting

The incidence or otherwise of pitting is another question which can only be decided by actual test, but I am of the opinion that there would be less pitting in the Novikov gear as the contact conditions are somewhat removed from those conditions which are known to be most conducive to pitting.

Running Speeds

I could have understood this claim better if it had referred to "permissible rotational speeds" instead of "permissible peripheral speeds." If, for a given application, the Novikov gear is made smaller than the involute gear, then its peripheral speed is smaller. Its rotational speed could therefore be increased before achieving the same peripheral speed as the involute gear. If noise and surface scuffing are the criteria by which speeds are limited, then it is difficult to believe that the Novikov gear can be run at higher peripheral speeds than the involute gear; if the claims for load capacity are sustained and taken advantage of by using smaller gears, then the rotational speed can be made higher. Comparative dynamic overloads, discussed under a later heading, must also be taken into account, and tend to show that at equal peripheral speeds, dynamic overloads on the involute gear are less than those on the Novikov gear.

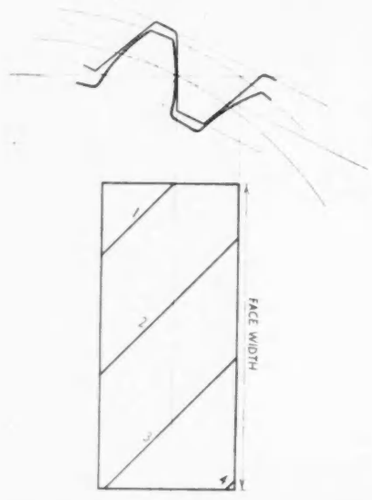

Fig. 2—Zone of contact of involute helical gears

Contact Conditions of the Involute, Arcuate and Novikov Gears

In coming to the inter-related questions of load capacity, point contact, and sensitivity to manufacturing errors, it is as well first to have clear definitions of what we shall be talking about.

Fig. 2 then, shows the helical gear of involute form in transverse section with the familiar "zone of contact" projected alongside. The contact takes place along the series of straight lines which move uniformly across the face width when the gears are revolved uniformly.

Fig. 3, which is reproduced from my analysis of twenty years ago, shows the true arcuate gear, with circular arc profiles of equal radii, which make only instantaneous contact on the transverse section, but give continuous motion when made in the form of helical gears. In this case the lines of contact are arcs, which show as straight lines when the zone of contact is viewed in the elevation shown, and these lines move uniformly across the face when the gears are turned uniformly.

Fig. 4 shows the Novikov gear (we shall consider only the helical type of Novikov gear) which is similar to Fig. 3 except that the radii of the wheel and pinion profiles differ by a small amount (exaggerated for diagrammatic clarity) so that the line of contact of Fig. 3 becomes a "point" in Fig. 4, and successive points again move uniformly across the zone of contact when the gears are turned uniformly.

Point Contact

An accepted method of comparing the contact stresses in different types of gear, and so arriving at an estimate of the comparative load capacities, is (subject to certain reservations) by means of the Hertz equations for the stress in elastic bodies which make either point or line contact. Kaluzhnikov, in his translation printed in the *Engineers' Digest*, describes the arcuate gear as the basis of Novikov's system of gear meshing, and he uses the Hertz formulæ to show that the contact stresses for a given torque are less in the arcuate gear than in the involute gear. He then states the preference for point contact for the sole reason that full arc contact cannot be attained in practical manufacture and mounting. I stress this because there seems to be a belief that the reduction from line contact to point contact is a virtue in itself, which is quite untrue. There is a very definite advantage in that it gives the arcuate gear many of the accommodating properties of the involute, but beyond this, it does not provide any additional load capacity, and the highlighting of "point contact" can only be regarded as a publicity extravaganza. I personally give highest credit to Novikov for the very simple and elegant device of profile modification which he has devised and which is an accomplishment in itself; good wine needs no bush. It is not, however, unnatural that enthusiastic supporters of the Novikov gear should overemphasise the virtues of "point contact," as it is the only feature which distinguishes

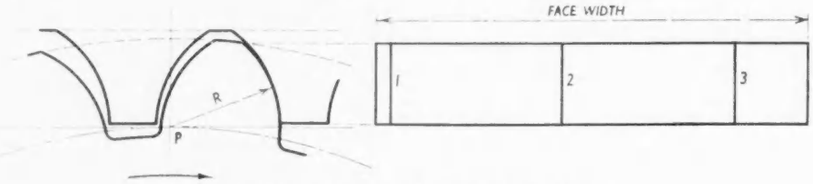

Fig. 3—Zone of contact of arcuate helical gears

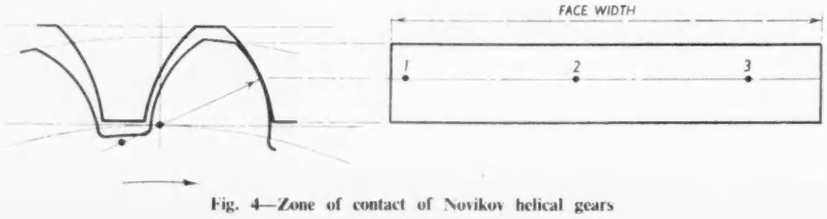

Fig. 4—Zone of contact of Novikov helical gears

the Novikov gear from known practice. The translated words of the patent specification are perhaps the ones which put this consideration of point contact most clearly :

" The radii of the tooth profiles may be similar in value and equal to the distance from the pitch point to the instantaneous axis. Then the centres of both profiles will lie on the instantaneous axis." This, of course, is a description of what we have called the arcuate gear. The same quotation then continues :

" In this case point meshing degenerates† into a particular form of line meshing, but this requires extremely high accuracy and absolute stability of the centre-to-centre distance, which in practice is not obtained. In designing the teeth one should restore the preference for the point meshing with a slight difference in the value of the radii of the profiles, having in mind that during technological and actual running in of the teeth the point meshing will approximate to the above mentioned line meshing, although the theoretical contact will then be of the point type."

Nowhere in the translation of the specification is there any claim that point contact does other than what is clearly stated in the above abstract, and it is made quite clear that every attempt must be made to get the closest approach to line contact whilst only permitting sufficient difference in the radii to allow the minimum necessary for the accommodation of manufacturing and deflection errors. If the reverse were true, that point contact does indeed improve load capacity, then why not go further and make the contact still more localised by engaging the arc form pinion with a straight sided wheel tooth, or a wheel tooth such as would be produced from a straight sided (conical) grinding wheel moving in a helical path without any generating motion. This would go even further to reduce manufacturing errors since the wheel would be of ideal simplicity.

Load Capacity

Although most of us have been taught to shudder at the thought of point contact between sliding and rolling surfaces on a gear or other mechanism, the term can be misleading and means nothing at all unless accompanied by a statement of the closeness of fit at the theoretical point of contact. The relative contact features of the involute gear and the Novikov gear may perhaps be visualised with the aid of the diagrams in Fig. 5.

These show at *A*, *B* and *C* the respective contact lines, or points, of the involute, the arcuate and the Novikov gear surrounded in each case by contour lines which illustrate in a purely diagrammatic fashion, the closeness of approach of the gear surfaces around the region where " no load " contact takes place. An area of surface proximity is thus defined.

A method of comparing the load capacity of different gears can be based on the Hertz method of determining stresses in elastic bodies subject to pressure. With this method it is possible to calculate the maximum contact stresses in gear teeth at the instantaneous contact. It only applies to static conditions of loading and when applied to moving gears it is subject to certain reservations which are dependent on the relative movement of the surfaces as influenced by lubrication. In conjunction with an empirical " speed factor " it is known to give reasonably accurate results when applied to involute helical gears, all of which have a similarity of surface movement. Its use may be open to some question if applied to a comparison of gear teeth which have fundamentally differing surface movements, such as the involute and the Novikov gear, but probably not to a sufficient extent as to cause serious error, and in any case it has already been used by the Russian writers on the Novikov gear, so that they apparently accept it as a reasonable basis of comparison. In my analysis of twenty years ago I made such a comparison of the comparative load capacities of the involute and the arcuate gear, and on reviewing this I have no reason to vary the conclusion reached at that time.

A particular case of the well-known Hertz analysis of contact stresses in solids under pressure is that in which two cylindrical surfaces make line contact. Similar conditions of contact occur on most gears having line contact, including both the involute and arcuate gear. By finding the radius of the curvature of the teeth in a plane normal to the direction of the line of contact, and knowing the total length of the line of contact, the Hertz conditions are simulated and the surface stress can be calculated. Using this principle and making one or two approximations (actually involute gears have conical contact rather than cylindrical contact) I derived an expression for the relative load capacity of involute and arcuate gears which in the ultimate

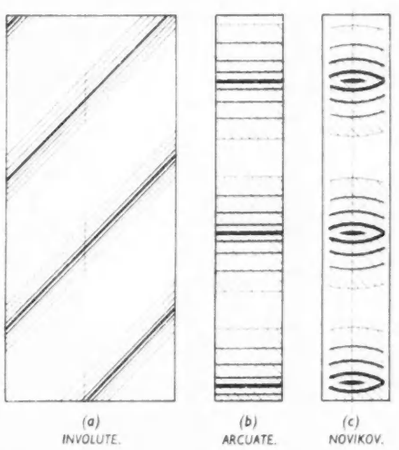

Fig. 5—This diagram illustrates by contour lines the surface proximity of involute, arcuate and Novikov gears

result depended only on the helix angle, and the pressure angle (mean pressure angle in the case of the arcuate gear) and the base lead angle of the involute gear. For the particular case of the normally used values of 30 deg. helix angle and 20 deg. pressure angle, it was shown that for involute and arcuate gears of the same size, the load on the arcuate gear could be 2·45 times that on the involute gear.

This result is based on the assumption of using the same helix angle and pressure angle as are normally used on conventional involute gears. It may be that these are not the optimum figures for the Novikov gear. A lower helix angle tends to reduce the stress because the loss in number of teeth simultaneously in contact is more than offset by the improvement in relative curvature at the place of contact.

Kaluzhnikov, after describing what we have called the arcuate gear as the basis of the Novikov gear, refers to the Hertz equation as being a means of stress comparison, and then proceeds to make a comparison of the relative curvature between the involute and the arcuate gear, both taken in a plane transverse to the gear axis. This, of course, leads to the conclusion that the relative curvature of the arcuate contact is infinitely greater than that of the involute. It would have been just as reasonable, and just as misleading, to say that the relative curvature of the involute, considered in a plane containing the involute line of contact, is infinitely greater than that of the arcuate gear. For a true comparison, the relative curvature of each gear should be considered in a plane normal to its own line of contact.

Coming now to the load capacity of the Novikov gear with its theoretical point contact, the particularisation of the Hertz expression for cylindrical contact no longer holds good, and if a calculation is to be made, it must be carried out by the much more difficult form of the Hertz equation for the general case of two non-uniform bodies making point contact. Fortunately it is quite unnecessary for our purpose to embark on this unpleasant task, as a little thought makes it immediately obvious that if our two imaginary cylinders are shortened in length (by reducing to or near to point contact) the contact stresses for a given total pressure must necessarily show some corresponding increase, since the specific pressure per unit length of line of contact is increased, even though the relative surface curvature is hardly altered.

This then leads to the overall conclusion that the contact stresses of the Novikov gear can never be less than that of the corresponding arcuate gear (apart of course from stress concentrations caused by manufacturing inaccuracies). It equally follows that the load capacity of the Novikov gear can never be more than two-and-a-half times that of the corresponding involute gear, but this is subject to all the reservations already referred to.

It is perfectly clear that the gears are being manufactured in Russia with a minimum difference between the radii of the tooth profiles so as to ensure the closest approach to line contact without resulting in interference caused by manufacturing or distortion errors near the crests of the teeth of either gear of a pair, and I am consequently prepared to believe that a load capacity ratio of something approaching 2½ can be achieved in practice, especially as the approximations which were used in calculating this ratio do, if anything, favour the involute form. But taking for the moment a speculative view of the various reservations I do not think that a much higher ratio than this can be obtained. If it should prove, over long experience, that this ratio of 2½ can be attained or nearly attained, it will indeed be a worthwhile achievement, especially if, as seems possible, the Novikov modification to point contact, in combination with modern improvements in manufacturing processes, overcomes the main obstacle which has always previously existed in the way of any competitor to the conventional involute.

Tooth Interference

There is an inherent interference in the arcuate gear in that if the rolling (pitch) circle of the larger gear is positioned on its circumference the points of the wheel teeth

† The word " degenerates " is obviously here used in a technical sense rather than in the English sense of reverting to a lower order. This is a misfortune of translation and perhaps the word " reverts " would have made the content more clear.

will dig into the solid metal of a pinion tooth of arc profile.‡

There are several ways of overcoming such interference ; in fact if the gears are produced by a rack cutter or hob, the interfering part would automatically be cut away. Another method which seems to have been adopted on the Novikov gear (judging from the few illustrations which have been reproduced from Russian sources) is to position the pitch (rolling) circles one just outside the circumference of the wheel, and the other near or below the root circle of the pinion—a perfectly satisfactory, if somewhat unconventional, solution. (This would not solve the problem for a Novikov gear design in which both gears have a full addendum and dedendum.) The Novikov modification to point contact would also, if carried to a sufficient extreme, overcome interference because the change in radius of curvature tends to cut away the offending part of the gear tooth. The fact that both these expedients are adopted on the Novikov gear confirms my opinion that the intention is to make the radius difference as small as possible, i.e. to make the "point" of contact as near to an "area" of contact as may be found practicable.

My own solution to this question of interference was to suggest profile radii on basic rack and its counterpart with both centres coincident and inside the pinion pitch circle, and lying on the line of pressure, with the result shown in Fig. 6.

Fig. 6—Interference between the tip of the wheel tooth and the base of the pinion tooth

This gives convex and concave profiles with point contact on the transverse section, but line contact in a plan view of the zone of contact. It may be conceded that if such a gear were given tip relief in accordance with modern practice, it would hardly differ, especially in practice, from the Novikov point contact gear.

There is no doubt, however, that the Novikov modification is extremely effective and shows great artistry. I do not think it has been fully realised that the Novikov modification really does achieve something of the variable centre distance properties of the involute gear. At the same time one cannot help observing that a basic rack having circular arcs on the normal section, arranged to give some tip and root relief, might be a more practical solution from the point of view of giving more facile manufacture of the tools and gears by existing processes, whilst giving all the advantages claimed for the Novikov method (Fig. 7).

For those who think that theoretical point contact should be avoided I would point out that it is used, perhaps less consciously than in the Novikov gear, on many types of gear other than helical, and is one of the advances made in recent years in gear technique and manufacture. All gears have theoretical line contact but this is frequently reduced to point contact either in the initial running of the gears, or nowadays more deliberately, in their manufacture.

Spiral bevel gears and worm gears are both examples of gears having theoretical line contact. Under variable load (and consequently variable deflection) or more simply by inaccurate mounting or manufacture, line contact cannot be maintained, and is reduced to point contact, but with a close proximity of the surfaces of the teeth. The modern method is to modify the teeth in manufacture so that the point contact exists from the beginning, and it is not left for the gears to wear in and damage themselves by prolonged running. A worm-wheel tooth is concave in the direction of its main contact lines, and the method consists in effect of increasing this curvature just sufficiently to ensure that there will be no interference at either end of the tooth face under the worst conditions of mounting and deflection likely to be met with. This is quite analogous to the Novikov modification in that line contact is reduced to point contact only by the minimum amount necessary to avoid the undesirable results of manufacturing and deflection errors.

Comparative Dynamic Overloads

It is quite likely that dynamic overloads on the Novikov gear will be higher than those on the corresponding involute gears, because of the more rigid tooth form with less tooth deflection. Some years ago, following a series of experiments on tooth deflection of involute gears, I suggested an empirical formula for finding the amount of tooth deflection for a given load acting on any tooth form, and suggested that, as a rough guide on comparative dynamic loads, the dynamic load tends towards a maximum which is equal to the load required to bend the combined teeth of a gear pair by an amount equal to the magnitude of the pitch errors. Applying this method, we find that the combined deflection on involute gears is more than 50 per cent greater than that of Novikov gears. Consequently, for an equal level of manufacturing errors, the maximum dynamic load for the involute gear is only two-thirds that of the Novikov gear.

The effects of axial load distribution, overlap ratio, and helix angle can only be decided by the results of prolonged practical usage and test. A lower helix angle than is usually adopted for conventional helical gears of involute form would favour the Novikov gear if examined strictly on the grounds of surface stress, but may not be favourable from a more practical view of achieving smooth running and avoiding violent changes in tooth loading on gears of narrow face width.

Manufacture

It is absurd to suggest that the Novikov gear is less sensitive to errors in manufacture than the involute, or that it can be manufactured on normal types of gear production machined with the same accuracy as the involute. The cutters for producing the Novikov gear are of more complex form and more difficult to test for accuracy than the simple straight-sided involute generating cutters. Errors in cutting depth, eccentricity of mounting of cutter or work have more effect on the Novikov than on the involute. Finishing the Novikov gear by grinding is impossible on many existing types of machine, and on those where it can be ground, special wheel trueing devices may be required in some, but not all, cases, which would increase the probability of errors.

If the Novikov gear, or any other modification of the true arcuate gear, becomes

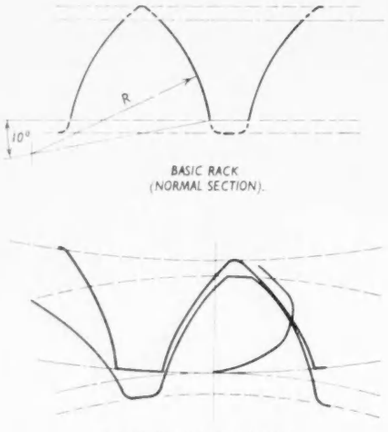

Fig. 7—Illustrating the use of a normal basic rack of arc form

widely adopted, it could lead to a changed outlook in the form and design of machinery for its production. One is led to speculate whether generating processes may even revert to form grinding processes or semi-generating processes. Why not ? One of the main advantages of the generators is connected with the involute form only, in that it enables simple and easily manufactured tools, or straight-sided grinding wheels to be used. On the other hand a generating process, as compared with a forming process, requires additional complications on the machine, all of which make for a less rigid form of machine, and additional transmission errors in the mechanism of the machine which are in turn transferred to the gear being produced. Most form cutting is antiquated and slow, but maybe this is because it has never been developed ; some form grinding machines are reasonably fast because they have been developed along with other modern improvements in engineering.

An interesting example of successful form cutting, and one which happens to have a particular bearing on our discussions of the Novikov and arcuate gears, is that shown in the photograph of Fig. 8. These gears have the full arc or basic Novikov profile, and have been successfully produced by John Holroyd and Co., Ltd., for many years. They are used for compressor rotors designed by Svenska Rotor Maschiner A.B.; the advantage of the arcuate form, which is used in its complete sense, is that the meshing teeth, when cut with little or no backlash, make a complete seal in the transverse section. A forming process for producing the tools and rotors was developed by Mr. Frank Stott of the Holroyd company and many thousands of rotors have already been made for some years, and machines have been made and supplied in many countries all over the world. The rotors can be either self-driving or connected by timing gears.

‡ In Fig. 6 the gears are assumed to be unequal in numbers of teeth and pitch diameters. AP is the arc profile of the wheel tooth and APQ is the arc profile of the pinion tooth. These arcs coincide over the length AP when their centre is at the pitch point O.

Since the length of the chord OP is equal to the length of the chord OQ, both being equal to R, it follows that the length of the arc OP is less than the length of the arc OQ, since the former is on a larger diameter circle than the latter.

Consequently, if the upper gear is rolled over the lower one without slip at the pitch lines, the point P at the corner of the wheel tooth will eventually reach a point P' inside the profile of the pinion, which is impossible in practice because the solid metal of the pinion tooth will prevent it.

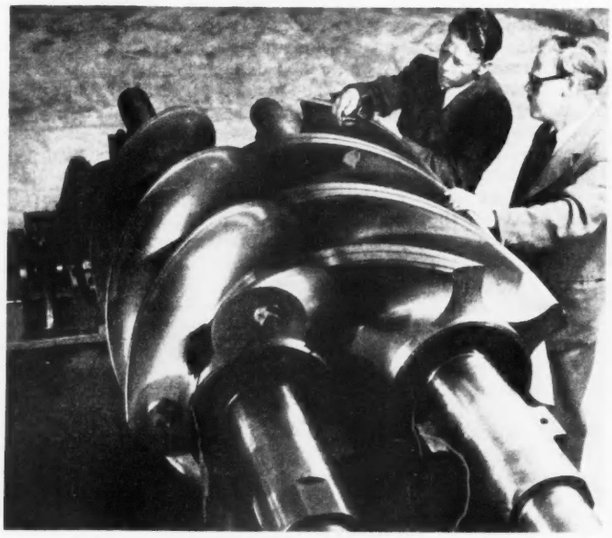

Fig. 8—This pair of helical gears of over 1ft circular pitch is an extreme case of the Novikov gear, in that a completely semi-circular tooth maintains instantaneous contact all round the profile and thus provides the seal which is necessary for their use as rotors. Such rotors have been designed by Svenska Rotor Maschiner A.B. and manufactured for some years by John Holroyd and Co., Ltd., using machines and processes developed by Mr. Frank Stott

An excellent testimony to the accuracy with which the rotors can be produced by form cutting is found in the fact that, when they are designed to be driven by timing gears, only the very best of modern gear machines are capable of making timing gears of such accuracy as will enable the rotors to be operated with the minimum tooth clearance and backlash with which they can be produced.

Application of Novikov Gears

I have been rather surprised that, according to the few reports I have read on the progress of introducing the Novikov gear in Russia, it seems to be used for general power transmission rather than special applications where its advantages, should they prove to be sustained, could be expected to show most effectively. It seems to me that the real value of the Novikov gear should begin where the involute ends. Very few involute gears for ordinary applications are at present designed to the limit of their possibilities, in the sense for instance of using the best class of materials and the most accurate production methods. For such everyday applications in which unhardened gears are used, if an increase in their load capacity is required, it may be thought better to consider first whether involute gears of the same size could be improved, rather than to change to Novikov gears. An added heat treatment operation, or even a gear grinding operation, might still keep the involute gear at a lower level of expense. There are however, other applications of gearing (particularly to modern developments) where the involute gear at its best and most expensive fails to meet the designers' requirements in that its weight or size causes a restriction in the full use of associated parts which may be far more important than the gears which drive them and where the expense of the gears is of little comparative importance. In some such instances the Novikov gear, or something like it, might have a far-reaching effect.

Gear Grinding Processes

Pursuing this line of thought, that a change from the conventional involute will show to greater advantage on the high quality class of gear application, we naturally think of case-hardened and profile ground gears, which, in addition to giving the best quality, also have the advantage for a non-involute form that the process bypasses many of the production difficulties which would otherwise arise. All operations up to the gear grinding stage could be done on standard machines without any particular difficulties and the onus of securing final form and accuracy would rest with the gear grinding process. With the accuracy that might be expected from gear grinding it should be possible to bring to a minimum whatever profile modification is necessary to ensure maximum contact without interference, and so approach as close as possible to the ideal conditions of the arcuate gear. Some existing gear grinding machines could be adapted with no more alteration than the provision of a suitable forming device for the shape of the grinding wheel. The Reishauer process of gear grinding seems to be one that could well be so adapted and used as a semi-generating process whereby a curve is preformed in the helical groove of the grinding wheel and used to generate the gear profile in the normal manner of this machine.

The Future Outlook

I promised at the outset to avoid discussion of any aspects on which there is not yet sufficient knowledge to reach a reasonably accurate conclusion, but I cannot refrain from expressing the opinion that the Novikov gear, or something on similar lines, has come to stay. It will be found to have advantages, perhaps not so great as those forecast by its sponsors, but sufficiently distinct to enable it in time to be adopted for a widening circle of application. An engineer of long experience once told me that the commercial value of a new idea depends one-quarter on the intrinsic value of the idea and three-quarters on the enthusiasm and effort put into its commercialisation, and I believe this to be a just estimate. The Novikov gear has its intrinsic value, and we must also believe from experience that the Russians will pursue this to its ultimate conclusion with determination.

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Thermal and Electrical Conductivities of Nickel-Chromium (Nimonic) Alloys

By R. W. POWELL, Ph.D., D.Sc., F.Inst. P., and R. P. TYE

Methods are described which have been used to determine the thermal conductivity, K, and electrical resistivity, ρ, of several nickel-chromium alloys (Nimonic 75, Nimonic 80, Nimonic 90, Nimonic 95, Nimonic 100 and Nimonic 105) at temperatures from 50 deg. to 800 deg. Cent., and, in one case, to 1000 deg. Cent. The values are tabulated and are shown to conform to within 6 per cent with the line, $K=2{\cdot}2\times10^{-8}(T/\rho)+0{\cdot}060$, T being the absolute temperature, K being expressed in joule centimetre per square centimetre second deg. Cent., and ρ in ohm square centimetre per centimetre. This equation is suggested as a means of deriving the thermal conductivity of other alloys of this kind from the relatively simple measurement of electrical resistivity.

ALLOYS of the Nimonic series were produced during the war period to withstand the high temperatures and severe working conditions of aircraft gas turbines. The first, Nimonic 75, was a modified 80-20 nickel-chromium alloy with an addition of about 0·3 per cent titanium, and Nimonic 80 followed in 1941 with the titanium content increased to about 2·5 per cent and possessing improved high-temperature creep resistance. This numbered series of Nimonic alloys has continued with Nimonic 90 and then in steps of five, each step indicating improved stress properties to higher temperatures, and at the time of writing has reached Nimonic 105.

Whilst heat conduction was not the primary property under consideration in the development of these alloys, it does influence both the thermal stresses developed and the ultimate working temperature and is accordingly of importance. During the inter-war period the National Physical Laboratory had established methods for measuring the thermal conductivity of metals to temperatures of 800 deg. to 1000 deg. Cent., and had actually published values for the thermal conductivity of an 80-20 nickel-chromium alloy to 800 deg. Cent.,[1] so was well placed for making determinations on the newly developed alloys when these were required. The values obtained for Nimonic 80 have already been published.[2, 3]

Samples of the post-war Nimonic alloys have been obtained and similar measurements made on these. As is customary when making such determinations on electrically conducting materials, parallel measurements of their electrical conductivities have been included. The additional measurement of electrical conductivity involves but little extra work and serves two useful purposes, it can confirm whether any changes observed in repeat values made at a lower temperature are spurious or due to the heat treatment;

• Communication from the National Physical Laboratory.

furthermore it is often possible to obtain a very useful correlation[3] between thermal conductivity, K, electrical resistivity, ρ, and the absolute temperature, T. The alloys at present under consideration were reasonably stable, so the first use gave no results of particular interest, but in connection with the second use it was found that all the results for the Nimonic alloys 75 to 100 conformed to the linear equation

$$K = 2{\cdot}2 \times 10^{-4}\left(\frac{T}{\rho}\right) + 0{\cdot}060$$

to within 5 per cent.

The work was regarded as complete when another alloy, Nimonic 105, came to our notice. Similar measurements were subsequently made on this alloy and the results obtained for the alloy were used as a check of the accuracy with which the equation could be used for the prediction of the thermal conductivity of a new Nimonic alloy.

Description of Samples

The Nimonic alloys tested were supplied in the form of rods 1in in diameter and 8in long. They were stated to conform to the chemical analyses given in Table I, and to have received the heat treatment recommended for them. See Publication No. 1303 *The Nimonic Alloys, Design Data*, Henry Wiggin and Co., Ltd.

Table I—*Chemical Compositions of Nimonic Alloys*

Alloy	Composition, weight per cent										
	C	Si	Cu	Fe	Mn	Cr	Ti	Al	Co	Mo	Ni
Nimonic 75	0·126	0·79	0·06	0·12	0·27	20·53	0·23	—	—	—	Balance
Nimonic 80*	0·04	0·5	—	0·5	0·6	21·0	2·5	1·2	—	—	Balance
Nimonic 90	0·06	0·65	0·14	0·41	0·03	19·5	2·45	1·40	16·5	—	Balance
Nimonic 95	0·10	0·65	0·06	0·38	0·06	19·1	2·91	1·99	16·5	—	Balance
Nimonic 100	0·24	0·28	0·04	0·18	0·03	11·1	1·07	5·22	20·0	5·0	Balance
Nimonic 105*	0·3 max.	1 max.	0·5 max.	3 max.	1 max.	14–16	0·5–2·5	4–6	18–22	4–6	Balance

* Nominal composition.

Description of Experiments

For the purposes of the thermal conductivity measurements, a cavity of $\frac{3}{4}$in diameter was drilled in the centre of one end of each test rod to a depth of $1\frac{1}{4}$in. The centre of the other end was drilled $\frac{1}{2}$in deep and tapped with $\frac{1}{2}$in British Standard Fine Thread. To this latter end was securely screwed a rod of Armco iron of known thermal conductivity.[4, 5]

Determinations at mean temperatures of from about 30 deg. to 200 deg. Cent. were made in the apparatus shown in Fig. 1, and from about 150 deg. Cent. to 800 deg. Cent. or higher in the apparatus shown in Fig. 2. In both assemblies the composite test rod is mounted centrally within a 3in diameter steel guard tube. The interspace is packed with a low-conductivity heat insulating powder, in order to minimise the transfer of heat by radiation, convection and conduction and more insulating powder is packed around and above the guard tube. In the moderate-temperature assembly the temperatures of the rods and guard tube were measured by means of 40 S.W.G. nickel-chromium and constantan thermocouples securely fixed at intervals along their lengths. Platinum and platinum alloyed with 10 per cent rhodium thermocouples were used in the high temperature apparatus. In both cases the thermojunctions were formed as a small bead by arc-welding, and the bead secured in a shallow, 75-gauge drill hole, by means of a pencil point. It will be seen that in Fig. 1, the test bar is in the lower position, and the cavity is closed with a rubber bung so as to allow cooling by water flowing at a constant rate in contact with the bar. By connecting calibrated and thermally insulated, differentially connected thermocouples in the inflowing and outflowing water streams, it is possible to make calorimetric measurement of the heat flowing at the base of the test rod.

The upper end of the composite bar and the top and centre of the guard tube can be heated electrically and adjustments made to bring points at corresponding levels of the bar and guard tube to closely matched temperatures. This is the optimum condition that should be attained when steady equilibrium temperatures are reached. In the apparatus of Fig. 1 the heat flowing into the test section is measured in terms of the thermal conductivity, cross-sectional area and temperature gradient in the standard bar, after correcting for any radial heat transfer through the insulating powder over the distance between the mean positions at which the gradients in the standard and test rods are measured. Similarly, the heat flowing out of the test section is measured in terms of the heat absorbed by the water-flow calorimeter after correcting for any radial heat transfer through the insulation over the distance from the mean position at which the gradient in the test rod is measured and the water-cooled end of the rod. A small correction is necessary for heat transfer from the surroundings to the differential thermocouples. After correction, these two values for the required heat flow in the test specimen agree to within 1 to 2 per cent. The mean value is equated to $K_T A_T dT_T/dl_T$ to give K_T, the thermal conductivity of the test material at the appropriate mean temperature (A_T is the area of the test bar and dT_T/dl_T the gradient in the test bar).

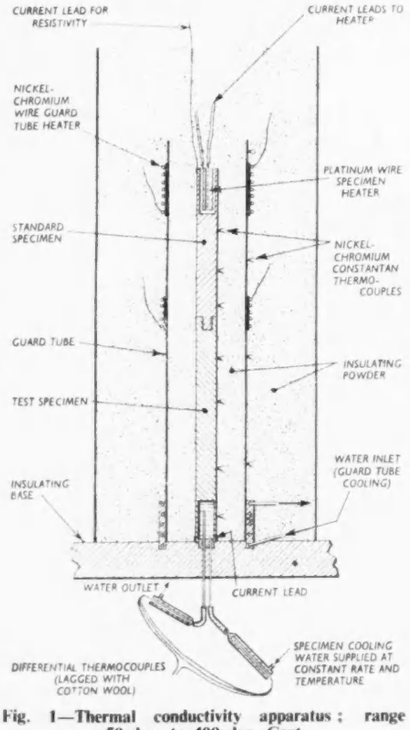

Fig. 1—Thermal conductivity apparatus; range 50 deg. to 400 deg. Cent.

The method used in the high temperature apparatus of Fig. 2 is very similar, but differs in that the test bar is now uppermost and only the heat out-flow to the standard bar can be derived. A steel cover sealed to the base plate by an O-ring allows this apparatus to be evacuated, all thermocouple wires and current leads being brought out through compressed rubber seals attached to the base plate. Vacuum conditions are used primarily to reduce the amount of oxidation of the specimens, but the consequent reduction in the thermal conductivity of the insulating powder reduces the correction that has to be applied for any mismatch of the mean temperatures of the rods and guard tube.

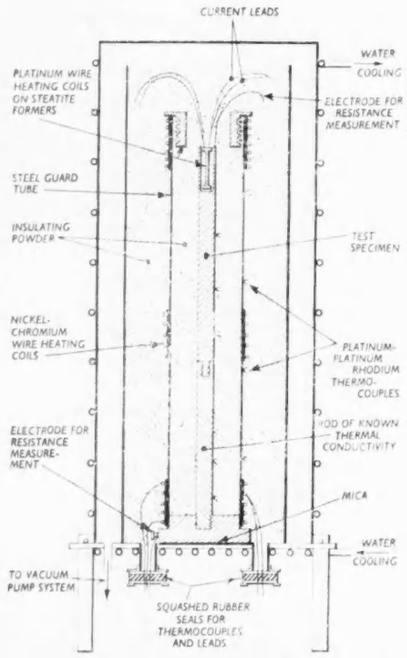

Fig. 2—Apparatus for thermal conductivity of metals and refractories at high temperature. Range 200 deg. to 1000 deg. Cent.

A knowledge of the effective thermal conductivities of the insulating powder for the actual conditions of the experiment is required. The value used was checked for experiments made for a range of similar but varying matched conditions, and from a plot of K_M against the mean difference in temperature between the rods and surrounding guard over their working lengths. The value of K_M was derived for a zero temperature difference. In the foregoing, K_M is the conductivity as derived from the measured heat flow in the standard bar without correcting for any radial heat transfer.

In this second method, since only one measurement of the quantity of heat flowing is made in each experiment it is essential for thermal conductivity values obtained in the over-lap region of 150 deg. to 200 deg. Cent. to agree closely with those of the first assembly. This ensures that the thermocouples are reading satisfactorily, and, once such agreement is obtained, the method can be used for measurements to mean temperatures of the order of 800 deg. to 975 deg. Cent., the limit being set by failure of heaters or of thermocouples.

During this work the temperature

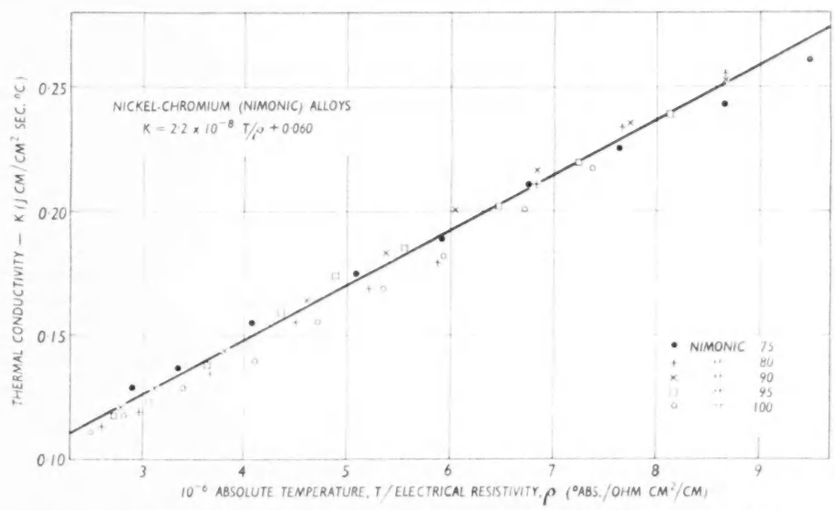

Fig. 3—Graph of thermal conductivity against absolute temperature divided by electrical resistivity

of the Armco iron did not rise above 600 deg. Cent., and up to this temperature there is good agreement between the values obtained by ourselves and other workers[6, 7, 8, 9, 10, 11, 12, 13, 14] for the thermal conductivity of this metal.

As shown in Figs. 1 and 2, current leads were secured to the ends of the composite rod so as to enable electrical resistivity measurements to be made on the various alloys whilst the thermal conductivity determinations were in progress. A current of the order of 4A was passed through the rods and a series-connected shunt of known value, and comparison made of the potential drops on a section of the rod and the shunt. Thermocouple arms were used as potential leads and measurements made immediately before and after reversal of the current in order to eliminate thermal voltages.

Results

The results obtained for the thermal conductivity and electrical resistivity of each alloy were plotted against the mean temperature and fitted with smooth curves. Thermal conductivity and electrical resistivity values read from these curves at 50 deg. and each 100 deg. Cent. are given in Table II, together with values of the Lorenz function, their product divided by the absolute temperature. These alloys are seen to have relatively low thermal conductivities which increase with increase in temperature, the rate of increase tending to become greater above about 500 deg. Cent. Their thermal conductivities are fairly comparable with those of austenitic steels, although their electrical conductivities are much lower. The electrical resistivities of each alloy only vary by 4 to 16 per cent over the temperature range studied, the greatest variation being for Nimonic 95. For each alloy the electrical resistivity has a maximum value at 500 deg. to 600 deg. Cent., and in this resembles the earlier 80-20 nickel-chromium alloy.

The values of the Lorenz function are unusually high. The theoretical value for electronic conduction is $2{\cdot}45\times10^{-8}$ joules ohm per second deg. Cent. deg. K., and it will be seen that the present values are about 80 per cent greater than this at 50 deg. Cent. and are still 20 per cent greater at 800 deg. Cent. This suggests that the lattice component of thermal conductivity amounts to these percentages of the electronic component and is unusually large.

The results given in Table II for the first five of the alloys to be tested, are reproduced in Fig. 3 where the thermal conductivity of each alloy is plotted against the corresponding absolute temperature, divided by electrical resistivity. The points are seen to all lie within 5 per cent of the straight line $K=2{\cdot}2\times10^{-8}(T/\rho)+0{\cdot}060$, and the conclusion was reached that the thermal conductivity of any further alloys of this type could probably be calculated to within this order of accuracy from a knowledge of their electrical resistivity.

Table III enables a comparison to be made between the experimentally observed values and values calculated in this way for two further alloys, the original alloy of nominal composition 80-20 nickel-chromium as determined by Powell in 1936 and the last and most complex alloy of the present series, Nimonic 105.

The calculated values for the thermal conductivity of the Nimonic 105 alloy at 50 deg. and 100 deg. Cent. are seen to be a fraction over 5 per cent greater than the observed, but all the other calculated values for these two alloys agree to within 5 per cent of the observed values. The observed points for Nimonic 105 depart systematically, and do in fact lie within 2 per cent of the line $K=2{\cdot}48\times10^{-8}\ (T/\rho)+0{\cdot}046$, but the whole series is still fitted better by the original line.

Table IV presents the values of L and C in the equation $K=L(T/\rho)+C$ which have been suggested from similar correlations made for other groups of alloys.

The alternative equation suggested by Fine was obtained from an examination of the results of other investigations of nickel alloys. It will be seen that for the 80-20 nickel-chromium alloy his equation leads to a value at 100 deg. Cent. which is 15 per cent too great, whilst for Nimonic 105 at 100 deg. Cent the value is 24 per cent too

TABLE IV—*Values of L and C for Various Metals and Their Alloys*

Main metal	$L\times10^8$ joule ohm/sec deg. Cent. deg. K	C joule cm/cm² sec. deg. Cent.	Reference
Aluminium	2·22	0·105	Powell and Hickman[15]
Copper	2·39	0·075	Smith and Palmer[16]
Iron (alpha)	2·43	0·092	Powell[5]
Iron (gamma)	2·39	0·042	Powell[5]
Magnesium	2·16	0·092	Powell[17]
Nickel	2·13	0·084	Fine[18]
Nickel alloys of Nimonic type	2·2	0·060	Present work
Titanium	2·62	0·0208	Deem, Wood and Lucks[19]
Titanium	2·38	0·0295	Powell and Tye[20]

TABLE II—*Thermal Conductivity and Electrical Resistivity of some Nimonic Alloys*

Mean temperature, deg. Cent.	Thermal conductivity, joule cm/cm² sec. deg. Cent — Nimonic alloy						Electrical resistivity, microhm centimetre — Nimonic alloy						Lorenz function × 10⁸, joule ohm/sec. deg. Cent. deg. K — Nimonic alloy					
	75	80	90	95	100	105	75	80	90	95	100	105	75	80	90	95	100	105
50	0·132	0·114	0·121	0·117	0·112	0·108	110·4	123·8	118·0	119·8	131·2	132	4·5	4·37	4·42	4·34	4·55	4·42
100	0·139	0·121	0·130	0·125	0·118	0·116	111·1	124·7	120·0	122·5	133·2	133·5	4·14	4·05	4·18	4·1	4·21	4·15
200	0·157	0·138	0·146	0·141	0·130	0·131	111·6	126·2	123·2	126·2	136·8	136·5	3·7	3·68	3·8	3·76	3·76	3·78
300	0·175	0·155	0·165	0·160	0·142	0·147	112·5	128·2	124·5	131·5	139·7	140	3·44	3·47	3·58	3·67	3·49	3·61
400	0·191	0·168	0·184	0·175	0·155	0·159	113·4	130·0	126·0	137·5	142·2	143	3·22	3·25	3·44	3·57	3·27	3·38
500	0·210	0·184	0·200	0·188	0·169	0·174	114·7	130·8	128·0	139·0	144·8	145	3·12	3·11	3·31	3·38	3·17	3·26
600	0·226	0·210	0·218	0·203	0·184	0·193	114·2	128·8	128·0	137·0	146·5	145·5	2·96	3·1	3·20	3·19	3·09	3·21
700	0·243	0·235	0·237	0·221	0·200	0·212	113·1	127·2	126·5	133·5	145·5	143·5	2·83	3·07	3·03	3·03	2·99	3·13
800	0·260	0·255	0·253	0·241	0·218	0·230	113·0	125·3	124·5	132·0	144·1	142	2·74	2·98	2·94	2·96	2·93	3·05
900	—	0·276	—	—	—	0·253	113·4	123·3	—	—	—	140	—	2·90	—	—	—	3·02
1000	—	—	—	—	—	0·276	—	—	—	—	—	137	—	—	—	—	—	2·97

TABLE III—*Comparison of Observed and Calculated Thermal Conductivities (joule cm/cm² sec. deg. Cent.) for 80-20 Ni-Cr Alloy and Nimonic 105*

Temperature, deg. Cent.	80-20 Nickel-chromium alloy — Thermal conductivity			Nimonic 105 — Thermal conductivity		
	Calculated	Observed	Difference, per cent	Calculated	Observed	Difference, per cent
50	—	—	—	0·114	0·108	5·5
100	0·136	0·140	−2·9	0·122	0·116	5·2
200	0·158	0·157	0·6	0·137	0·131	4·6
300	0·175	0·174	0·6	0·151	0·147	2·7
400	0·194	0·1885	2·9	0·164	0·159	3·1
500	0·213	0·2135	−0·2	0·178	0·174	2·3
600	0·232	0·230	0·9	0·193	0·193	0·0
700	0·2545	0·247	3·0	0·210	0·212	−0·9
800	0·2745	0·264	4·0	0·227	0·230	−1·3
900	—	—	—	0·245	0·253	−3·2
1000	—	—	—	0·265	0·276	−4·0

great. Whilst clearly not so well suited for application to alloys of the present type, results for Monel,[1] a 70-30 nickel-copper alloy, are much better fitted by Fine's equation. The present equation is recommended for use with the high nickel-chromium alloys of the Nimonic type.

ACKNOWLEDGMENT

The authors are indebted to The Mond Nickel Company, Ltd., for the supply of the alloys on which the measurements were made, and particularly to Dr. W. Betteridge of that company for his interest. Miss M. J. Woodman assisted with the experimental work. The work has been carried out as part of the research programme of the National Physical Laboratory, and this paper is published by permission of the Director of the Laboratory.

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Vacuum Testing of Tube Elements for Steam-Raising Units

By M. S. HAYWARD, B.Sc.*

A high-vacuum process for the testing of tube elements for the steam-raising units at the Hunterston nuclear power station (South of Scotland Electricity Board) is described here. The test is designed to ensure that the maximum leakage of water into the coolant circuits of each reactor shall be well within the capacity of the CO_2 drying plant—in this case 6 lb (2·7 kg) of water per hour. The charcoal-Pirani-gauge method, which depends on preferential absorption, was chosen because it is reliable, simple and suitable for use in a works.

LEAK-DETECTION techniques involving the use of high-vacuum methods have, during recent years, come to be accepted as the most rigorous and sensitive available. Unlike other forms of non-destructive testing, leak-detection methods are employed simply to establish whether or not there exist faults extending throughout the full depth of the weld, joint, or vessel wall being tested. For this reason they are not sufficient in themselves as tests of welding standards or for proving the soundness of metal plate or tube, since although the occurrence of a leak is sufficient evidence of the existence of a fault, the absence of leaks does not necessarily establish the absence of faults. It is preferable, therefore, to employ leak-detection methods in conjunction with either tests for mechanical strength, for example, hydraulic tests, or examinations of the metal structure by radiographic, ultrasonic, or other methods, for testing to be completely comprehensive.

Not only do high-vacuum leak-detection techniques offer very sensitive testing facilities, but they also provide the means for estimating the degree of leakage to be expected under operating conditions.

This article describes the method of application of a high-vacuum process to the testing of the tube elements for installation in the steam-raising units of the South of Scotland Electricity Board's Hunterston nuclear generating station. The purpose of the test is to ensure that for each reactor unit the maximum possible leakage of water into the coolant circuits shall be well within the capacity of the carbon-dioxide drying plant, which in this case is capable of handling 6 lb (2·7 kg) of water per hour whilst still maintaining a satisfactorily low level of concentration in the gas.

TEST REQUIREMENTS

Since the mechanism of the flow of gases and liquids through small leaks depends upon the physical dimensions of the leak itself, it is not possible to predict accurately the flow of water or steam under pressure which will take place through a leak measured under high vacuum conditions, but a sufficiently reliable estimate may be obtained by the analysis of Santeler and Moller.[1] By considering the different conditions of temperature and pressure which exist throughout the steam circuit, and hence the different values of viscosity and density of the steam or water present, it is possible to estimate the maximum leakage of steam or water from each bank of tubes and deduce the total possible water leakage into the gas circuit. As a result of this estimate, it was decided that each element should be tested for air leaks greater than 2×10^{-2} litre microns per second (equivalent to $2{\cdot}6\times10^{-5}$ cubic centimetres per second at 1 atmosphere) under vacuum conditions. Table I shows the maximum amount of water leakage which could occur in each tube bank in the unlikely event of leakage of every element at the maximum permissible rate.

TABLE I—*Maximum Possible Amount of Water Leakage from Accepted Elements*

Unit	θ	Δ_p	L_s	L_w	L
H.P. superheater	314	31	200	—	0·67
L.P. superheater	273	1·1	1·26	—	10^{-3}
H.P. evaporator	245	35	250	25·1	17·23
L.P. evaporator	190	2·8	2·51	1·58	0·27
H.P. economiser	163	34	—	15·8	3·75
L.P. economiser	163	2·4	—	0·79	0·09

θ = mean temperature of steam or water (deg. Cent.).
Δ_p = mean pressure difference, CO_2—steam (atmospheres).
L_s = maximum steam leakage per element (10^{-4} atmospheres per cubic centimetre per second).
L_w = maximum water leakage per element (cubic centimetres per day).
L = maximum water leakage per reactor (pounds per day, 0·45 kg per day).

The elements are fabricated in seamless steel tube of 1¼in (32mm) bore with welded fins, and the length of tubing in each element varies from approximately 200ft (60m) in the economiser elements to almost 500ft (150m) in the largest evaporator elements. The vacuum test was to be applied at the manufacturer's works after the elements had been subjected to a hydraulic test.

CHOICE OF METHOD

In deciding on the precise method of testing to be employed, a number of factors of a non-technical nature had to be borne in mind. First, the vacuum equipment was to be used in a sub-contractor's works where no special laboratory or instrument facilities would be available and, secondly, although the personnel operating the equipment would be trained in the use of high-vacuum techniques, they would not be highly skilled in the operation and maintenance of electronic instruments. They would also be working with the minimum of direct supervision. It was therefore desirable that the equipment should be sufficiently robust and simple to continue working under adverse conditions with a minimum of maintenance. Furthermore, it was probable that the internal surfaces of the tubes would be contaminated with water vapour and possibly oil after being subjected to the hydraulic test. As a result of these considerations and bearing in mind that the sensitivity required was not of a particularly high order, it was decided that the charcoal-Pirani-gauge method was the most suitable. This method depends for its operation on the fact that activated charcoal, when suitably cooled, adsorbs hydrogen much less readily than all other gases. Thus, if a cooled charcoal trap is placed between the evacuated element and a Pirani gauge, this gauge will respond preferentially to hydrogen and by surrounding the element with a hydrogen atmosphere an overall "proving" test may be carried out. This technique is fully described by Kent.[2] The main attraction of the method lies in the fact that it provides a means for detecting leaks as small as 10^{-3} litre microns per second (lusec) by the use of standard vacuum apparatus, the only addition to the normal vacuum pumping and measuring equipment being the charcoal trap. The apparatus is, as a result, cheap to install, reliable and such as to require no highly specialised maintenance during service.

It was appreciated that the response time of the equipment was likely to be slow, but this is a limitation imposed by the shape of the objects being tested, a very large resistance to pumping being presented under vacuum conditions. However, this is not a serious disadvantage in a system such as this, which is designed to prove the leak tightness of each element overall rather than to determine the precise location of any leaks found.

HIGH-VACUUM DESIGN CONSIDERATIONS

The principles involved in the design of such a high-vacuum system can be more easily understood by bearing in mind the close analogy that exists between vacuum systems and d.c. electrical circuits. In the former a resistance Z can be defined, such that :

$$Z=(p_1-p_2)/Q, \text{ where } p_1>p_2 \quad . \quad (1)$$

where (p_1-p_2) is the pressure difference across that part of the system considered, and Q is the quantity of gas flowing in unit time. In many cases the conductance C is more useful, where :

$$C=1/Z=Q/(p_1-p_2) \quad . \quad . \quad . \quad . \quad (2)$$

As in electrical theory, for resistances in series :

$$Z\,(\text{total})=Z_1+Z_2+Z_3+\ldots,$$

and for resistances in parallel :

$$C\,(\text{total})=C_1+C_2+C_3+\ldots.$$

* G.E.C.-Simon-Carves Atomic Energy Group.

The conductance of a component can also be defined in terms of the inlet pressure only. This is referred to as the speed, S, where :

$$S = Q/p_1 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Two further points require consideration :

1. The resistance of a section of a vacuum system is not necessarily constant, but may be a function of Q and p.

2. There is no analogy between a vacuum pump and an electric cell, and the pump therefore has no characteristic comparable with an electromotive force.

Pump Speed.—The speed, S_P, of a pump is defined as the volume of gas removed per unit time from a vessel, the volume being measured at the pressure at the inlet to the pump. Hence, since the gas laws are obeyed accurately at low pressures :

$$S_P = (dV/dt)_p = Q/p \quad . \quad . \quad . \quad (4)$$

This is of the same form as the conductance of a component, although the conductance of a pump, when working, has no real meaning since Q is moving against the pressure gradient.

Consider now a vessel kept at constant pressure p_1, connected through a resistance Z to a pump of speed S_P at a pressure p_2. Let the throughput be Q and the speed of the whole system S_t. Then from the equations given above :

$$Z = 1/C = (p_1 - p_2)/Q,$$

$$1/S_t = p_1/Q,$$

$$1/S_P = p_2/Q,$$

and hence

$$\frac{1}{S_t} = \frac{1}{C} + \frac{1}{S_P} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

This equation is fundamental in vacuum technology. It shows that for all practical purposes the speed of a pump can be dealt with as a conductance, and thus can be combined with other conductances as described above.

It follows that, given a fixed conductance C, it is uneconomic to specify a pump having a speed greater than three or four times this in an attempt to achieve a higher rate of evacuation. This is illustrated in Fig. 1.

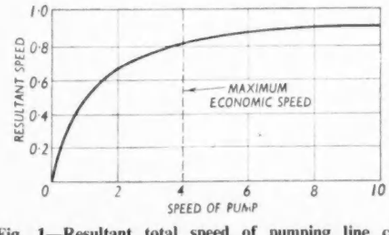


Fig. 1—Resultant total speed of pumping line of unit conductance in series with pumps of different speeds (arbitrary units)

Flow of Gases Under Vacuum.—The equations governing the transfer of gases under vacuum are determined by the combined effects of the dimensions of the duct or vessel through which the gas is flowing and the pressure of the gas. Two extreme cases can be recognised, one when the mean free path (m.f.p.) of the gas molecules is very much smaller than the dimensions of the vessel, the other when the mean free path is comparable to or larger than the size of the container. In the first case, normal hydrodynamic equations apply ; in the second the gas molecules collide more often with the walls of the container than with each other, and each one finds its way through the system independently. Between these extremes there is a region where the characteristics of both types of flow are exhibited.

For air at 20 deg. Cent. the limits of the three regions can be defined as below, where p_m is the mean pressure in microns of mercury, and d is the characteristic dimension of the vessel in centimetres :

(i) Viscous-flow region,

$$p_m d > 500,$$
$$\text{m.f.p.} < 0{\cdot}01d ;$$

(ii) Intermediate region,

$$15 < p_m d < 500,$$
$$0{\cdot}33d > \text{m.f.p.} > 0{\cdot}01d ;$$

(iii) Molecular-flow region,

$$p_m d < 15,$$
$$\text{m.f.p.} > 0{\cdot}33d.$$

Conductance of Pipes.—In the viscous-flow region, passage of the gas is governed by Poiseuille's equation for a gas at constant temperature, namely :

$$\frac{n}{t} = \frac{\pi r^4}{16\eta} \frac{1}{RT} \frac{p_1^2 - p_2^2}{l},$$

where n/t is the throughput in moles/unit time, r and l the radius and length of the tube respectively, p_1 and p_2 the inlet and outlet pressures, η the viscosity at the temperature T deg. K, and R the gas constant.

Using the fact that $Q = pV/t = nRT/t$, and taking the mean pressure $p_m = \frac{1}{2}(p_1 + p_2)$, with the tube diameter d, this can be written more conveniently as :

$$Q = \frac{\pi d^4}{128\eta} \frac{p_m(p_1 - p_2)}{l}.$$

Hence the viscous conductance of a cylindrical pipe is given by :

$$C_v = U_v d^4 p_m/l, \text{ where } U_v = \pi/128\eta.$$

In the molecular-flow region, Knudsen's hypothesis is valid, a gas molecule that strikes the wall being assumed to be momentarily adsorbed and then emitted in a random direction. This gives, for a circular pipe :

$$Q = \frac{4}{3}\left(\frac{2\pi}{\rho}\right)^{\frac{1}{2}} \frac{(p_1 - p_2)r^3}{l},$$

where ρ is the gas density at unit pressure. The molecular conductance is therefore :

$$C_m = U_m d^3/l, \text{ where } U_m = \frac{1}{6}(2\pi/\rho)^{\frac{1}{2}}.$$

In the intermediate region, both mechanisms are operative, and equations have been developed on the basis of Maxwell's theory of slip to include both the d^4 term characteristic of viscous flow and the d^3 term characteristic of molecular flow. The total conductance of a circular pipe can then be expressed as :

$$C = \frac{U_v d^4 p_m}{l} + \frac{U_m d^3}{l} \frac{1 + K}{1 + 1{\cdot}24K} \text{ (c.g.s. units)},$$

where

$$K = \rho^{\frac{1}{2}} d p_m/\eta.$$

Values of C for a variety of pipe diameters over a range of pressures are given in Fig. 2.

Cold Traps.—Under high-vacuum conditions a refrigerated trap also has a pumping speed associated with it, owing to the fact that it will remove condensible vapours from the system in a way similar to that of a pump.

The speed is given by :

$$S = 11{\cdot}6(29/M)^{\frac{1}{2}} A(1 - p_2/p_1) \text{ litres per second},$$

where M is the molecular weight of the condensible material, p_1 its partial pressure

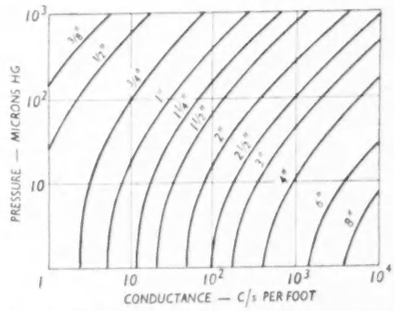


Fig. 2—Conductance of cylindrical tubes per 1ft length as a function of diameter (end effects neglected)

in the system, p_2 the vapour pressure of the condensible material at the trap temperature, and A the effective area of the trap in square centimetres.

It is clear that the minimum speed of the trap is zero, when $p_1 = p_2$, and that its maximum speed, when $p_2/p_1 \to 0$ (a common condition), is :

$$S_{max} = 11{\cdot}6\,(29/M)^{\frac{1}{2}}\,A \text{ litres per second.}$$

Design of System

The flowsheet of the equipment installed as a result of the considerations outlined above is shown in Fig. 3. An Edwards

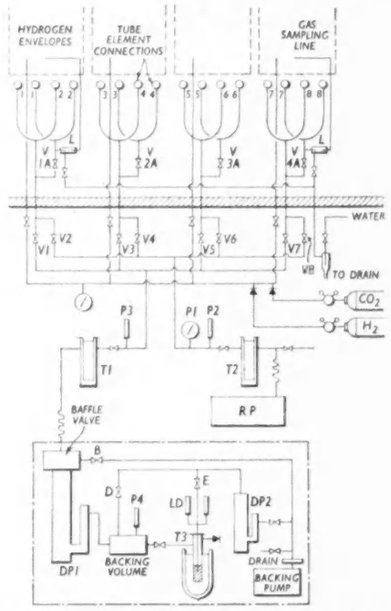
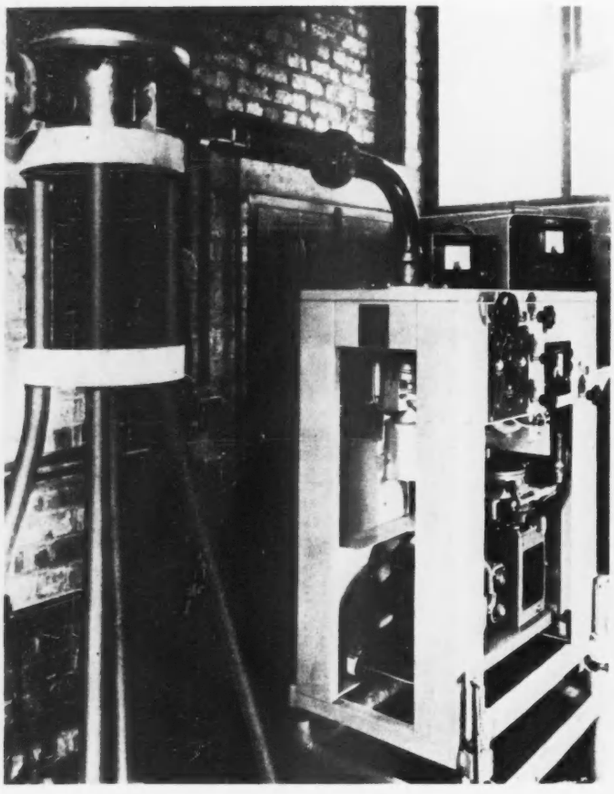


Fig. 3—Flow diagram of the equipment used for routine testing

GKS.27 rotary vacuum pump, RP, of 750 to 1 per minute displacement is used to evacuate the elements initially from 1 atmosphere down to a pressure of approximately 50 microns of mercury. This particular pump was chosen since its pumping speed over this range of pressures is approximately three times the conductance of eight tube elements connected in parallel. At a pressure of about 50 microns, when the pumping speed of the rotary pump is greatly reduced, further pumping is carried out instead by the pumps DP_1 and DP_2. These are oil diffusion pumps, of 2in (50mm) and 1in (25mm) bore respectively, having a maximum pumping speed of 50 litres per second. The choice of these pumps was again determined by the maximum conductance of the tube



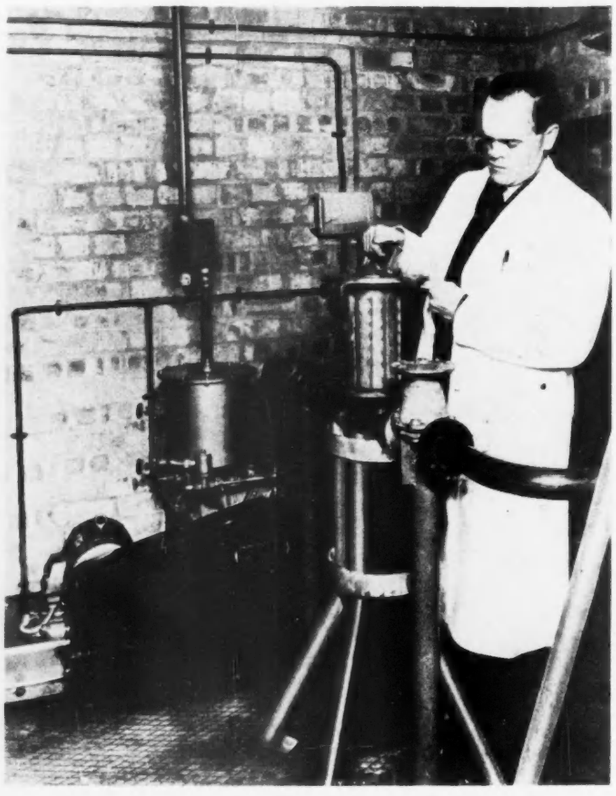


Fig. 4 (Left)—General view of pumping set, showing cold trap on the left. Fig. 5 (Right)—The cold trap incorporated in the line from the roughing pump, showing the finned stainless steel insert. Note also the condensate separator fitted to the exhaust of the pump

elements in this pressure range, bearing in mind that the function of the diffusion pumps when leak detecting is to pump out hydrogen rather than air. The charcoal trap T3 and the leak-detector heads *LD* are placed in the backing space of the primary diffusion pump, since it is in this part of the system that the highest concentration of probe gas will occur. By siting the gauge between the diffusion pumps two advantages result. First, any occluded hydrogen which may be evolved from the backing-pump oil is prevented from reaching the leak-detector head and giving spurious results. Secondly, the degree of pressure fluctuation at the gauge head, which is the chief factor limiting the sensitivity of the method, is reduced to a minimum because of the continuous pumping action of the diffusion pumps. By use of the throttling valve *E* the pressure at the leak detector may be increased for maximum sensitivity. Valves *B* and *D* are provided for by-passing the diffusion pumps and/or the leak-detection head if necessary. Fig. 4 is a general view of the high-vacuum pumps and instruments which were built into a self-contained unit within a steel framework by Edwards High Vacuum, Ltd., of Crawley.

The cold traps *T1* and *T2* (Fig. 3) are provided both to protect the pumps from condensible vapours and to provide a high rate of extraction of water vapour. They are constructed in the form of double-walled vessels, the inner container being filled with a mixture of solid carbon dioxide and industrial alcohol, providing a temperature of −78 deg. Cent. At this temperature water has a vapour pressure of approximately $6{\cdot}0\times10^{-4}$mm of mercury. The design of these traps is a compromise between the provision of high conductance to pumping whilst at the same time ensuring that in passing through the trap the gas is at all times kept in close contact with the cooled surface. The inner vessel is constructed from stainless steel in order to minimise the heat input to the coolant by conduction and also to ensure that the top flange, which is sealed by means of a rubber O-ring, does not reach too low a temperature. Some degree of insulation is provided for the coolant by virtue of the fact that the inner container is surrounded by the vacuum space, and the area of the condensing surface is increased by the provision of vertical fins welded on to the outside of the inner container (Fig. 5). Although the rotary pump is capable of extracting large quantities of water vapour owing to the provision of the gas-ballast facility, a cold trap is still desirable. This is because the speed of evacuation of the rotary pump in an application such as this falls very rapidly as the pressure is reduced below about 1mm of mercury, whereas the pumping speed of the

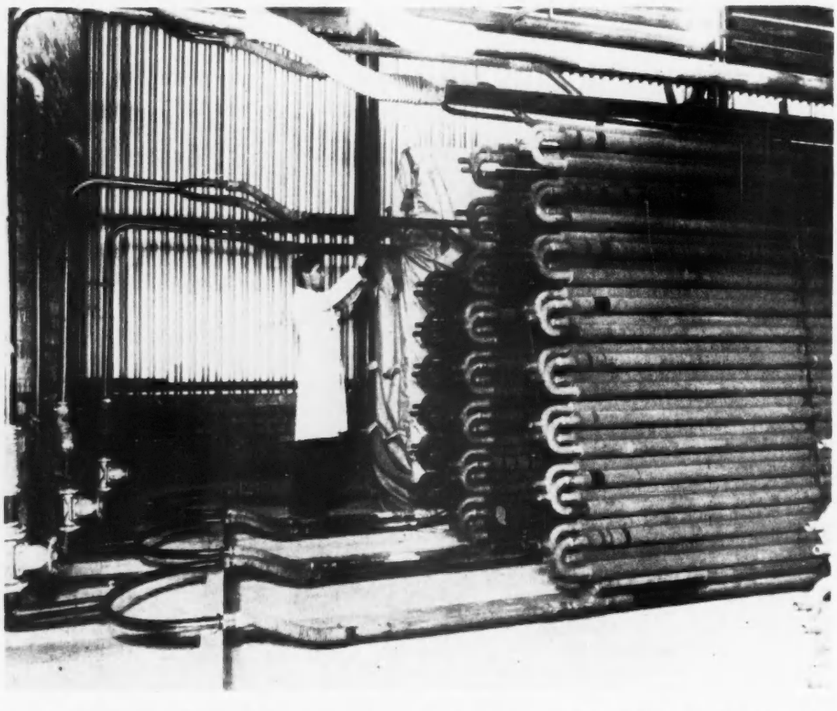


Fig. 6—Tube elements in position for testing. (Nylon hoods removed from the nearer elements for clarity)

cold trap with respect to water vapour, as shown above, is very high.

Valves *V1* to *V8* provide the means for pumping on either pump any number of pairs of elements up to the maximum of eight elements simultaneously. Pressures within the range 0–40mm of mercury are read on a barometrically compensated dial gauge P_1, Pirani gauges P_2, P_3 and P_4 being used to read pressures below about 500 microns of mercury.

When conducting the test, each pair of elements is covered with a proofed nylon envelope which is first filled with carbon dioxide, then with hydrogen. The carbon dioxide is used in order to minimise the fire risk associated with the use of large volumes of hydrogen. All the control valves for these operations are situated within the pumping room so that a complete test sequence may be carried out without entering the hydrogen bay.

In order to provide an indication of the magnitude and speed of the response of the apparatus (which will vary according to the size of the elements and the condition of their inner surfaces), calibrated leaks,[3] *L*, of 2×10^{-2} lusec are coupled to the ends of the elements furthest from the pumps. These are utilised by drawing a sample of the hydrogen-carbon-dioxide atmosphere from within the envelope by means of a water-jet extraction pump and discharging it on to the calibrated leak. The response so produced on the instrument is the maximum that could still result in acceptance of the element.

The pumping manifolds are fabricated mainly from welded seamless steel tubing of 2in (51mm) diameter, this size of tubing providing the maximum economical overall speed of evacuation of the elements.

After being subjected to a hydraulic test and prior to undergoing the vacuum test, each element has to be thoroughly dried. This is done by stacking a number of them under a sheet-metal shroud and heating them by means of gas burners to a temperature of approximately 200 deg. Cent. At the same time dry air is blown through them by means of a centrifugal fan, the air flow through each element being maintained at not less than 8 cubic feet (0·23 cubic metres) per minute. After drying, the elements are then moved by means of overhead rails into the testing bay, where they are supported on the floor in a vertical plane (Fig. 6). The elements are pumped initially from both ends in the interests of rapid initial evacuation and degassing, but during the test pumping is continued from one end of the element only by closing valves *V1A* to *V4A*. This is done in order that the calibrated leak may be used in a part of the system as remote from the leak detector as any leaks that may occur in the elements.

The hydrogen envelopes are fitted on to the element pairs before they are connected to the vacuum system, these connections being made outside the envelopes to avoid the necessity for making the unions vacuum-tight to hydrogen; the lower edges of the envelopes are sealed to the floor by means of sand-filled bags.

Performance

This equipment has been in use for some weeks at the works of Richards and Ross, Ltd., Wednesfield, tube manipulators manufacturing elements for the Hunterston generating station; at the time of writing, a total of approximately 300 elements has been tested, none of which has been found to be faulty. It has been established that sixteen elements per day can be tested, although this total depends largely on the handling facilities available and on the siting of the testing equipment in relation to the fabrication area. The time required to evacuate the elements to pressures suitable for leak detection varies greatly according to the effectiveness of the drying procedure and the physical dimensions of the elements, but with the smaller sizes it has been found possible to carry out a test at a pressure of 20 microns of mercury after one and a half hours' pumping, the pressure in the backing space being maintained at approximately 60 microns.

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Optimum Pulley Positions for Level-Luffing Cargo Cranes

AN APPLICATION OF THE ELECTRONIC COMPUTER TO CRANE DESIGN

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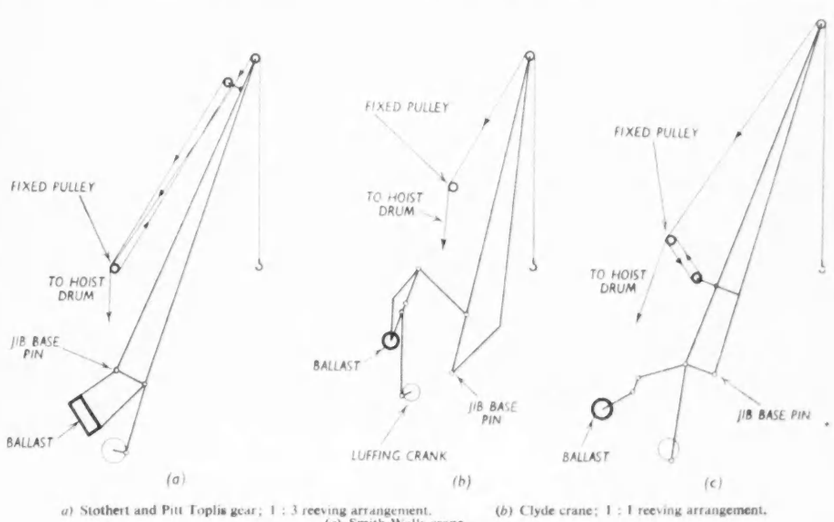
Most cargo cranes are designed so that when the jib alters its inclination there is little vertical "wander" in the resulting load path. Such level-luffing gives important advantages. In many cranes it is achieved by special methods of reeving the hoist rope(s), though no such arrangement gives perfect *level-luffing. The best position(s) for the specially-located fixed pulley(s) can be approximated fairly well, in certain cases, by graphical methods; otherwise trial and error calculations are required. This article explains how such positions have been found by the electronic computer, using a simple "hunting" procedure. The path(s) traced out by the pulley(s), along with the decreasing torque range on the luffing drive, provide the crane designer with invaluable information.*

WITH an ordinary jib crane the load is involuntarily raised and lowered as the jib is luffed (or "derricked") in and out. Some method of "level-luffing" is usually considered desirable for a cargo crane, however, so that the load will move approximately horizontally during the luffing motion. The crane driver can then associate pure radial, tangential and vertical movements of the load with the luffing, slewing and hoisting controls, and can therefore achieve greater precision with greatly increased speed in the handling of cargoes. The dead weight of the jib itself is usually balanced, on this type of crane, so with level-luffing there is little power required for the luffing motion; this means that the luffing motor and the mechanism connecting it to the jib can be reduced in size and weight.

One of the most successful level-luffing mechanisms was patented in 1912 by Claude Toplis,[1] then chief designer to Stothert and Pitt, Ltd., of Bath. It requires two pulleys, one just behind the other at the head of the jib, and a further two pulleys, side by side at the top of an "A" frame built up from the main body of the crane. The rope from the load passes over one of the jib-head pulleys, round a fixed pulley on the "A" frame, back to and round the second jib-head pulley, back and over the second pulley on the "A" frame and thence to the winding drum. If the fixed pulleys are positioned correctly this arrangement gives almost perfect level-luffing, and is one of the main features of the present day Stothert and Pitt general purpose cargo crane. It is shown diagrammatically in Fig. 1 (*a*).

Two similar level-luffing mechanisms are also in current use. The first of these requires only single pulleys at the jib head and the top of the "A" frame, and so has only one rope "return" at the back of the jib instead of the three "returns" on the original Toplis arrangement. It was patented in 1922 by Mannock[2] and is mainly used for grabbing cranes, which require double hoist



(*a*) Stothert and Pitt Toplis gear; 1 : 3 reeving arrangement. (*b*) Clyde crane; 1 : 1 reeving arrangement. (*c*) Smith-Walls crane.

Fig. 1—Different types of rope-adjusted, level-luffing mechanisms in cargo cranes

ropes all the way. The second variation has points in common with the other two and was devised in 1928 by Walls[3] of Thomas Smith and Co., Ltd., of Rodley, Leeds. In this mechanism the second jib-head pulley of the 3 : 1 Toplis arrangement is moved down to a position at the back of the jib near to the jib pivots; thus there is only a single return from the top of the jib, with two additional returns from the second pulley lower down. These further mechanisms are shown diagrammatically in Figs. 1 (*b*) and 1 (*c*).

From a mathematical viewpoint the Smith-Walls mechanism may be considered the general case, for it reduces to the 3 : 1 Toplis and the 1 : 1 Mannock arrangements if the lower pulley on the jib is moved to the jib-head, or to some fixed point (at the pivot at the jib base or to the top of the "A" frame, for example). The position of the fixed pulleys at the top of the "A" frame has to be varied for best results in these three different cases; for the Smith-Walls mechanism this position has to be determined at the same time as that of the lower jib pulley. The problem of finding the best positions for these pulleys, to minimise both the vertical "wander" of the load and the range of the extreme positive and negative torques required from the luffing motor, was solved by the authors, using the electronic computer. The torque on the luffing motor can also be varied, if necessary, by adjusting the balance weights.

These optimum pulley positions are dependent on the maximum and minimum radii of operation of the crane, that is, on the extreme angles of inclination of the jib if the jib length is taken as the unit dimension. These angles are fairly constant, except for special purpose cranes, so the results described below may be considered representative.

The determination of the optimum position of the fixed pulley in the 3 : 1 Toplis mechanism presents little difficulty. It was found, in fact, that the computer solution agreed almost exactly with that already obtained and used in the current Stothert and Pitt general purpose cargo crane. The other two crane mechanisms presented more of a problem, and are further considered below.

There are several other types of level-luffing mechanism in current usage, but they employ linkages, cams, screw-jacks and other devices rather than pulleys and the hoist rope; they are not considered here.

Theory for the Load Path and the Luffing Shaft Torque

If the pulleys are all of the same size, the length of rope in contact with them remains constant whatever the inclination of the jib; it is therefore permissible to use the pulley centres in calculating the height of the load path. The symbols required for the mathematical development are shown in the outline diagram of the Smith-Walls crane in Fig. 2, where the jib pivot, the lower jib pulley and the jib head are marked as *O*, *A* and *B* respectively, and the fixed pulley at the top of the "A" frame as *F*. The line *FA* extends to meet *OA* in a variable point *C*. Constant lengths are denoted as follows: *OF* as *a*, *OA* as *b*, *OB* as *l*, and the length of the rope between the load and the fixed pulley *F* as *s*. Variable lengths are denoted thus: *FB* as *m*, *FA* as *n*, and the height of the load above the horizontal *OX* as *y*. The constant angles *XOF* and *AOB* are written as α and β, and the variable angles *XOB*, *OBF*, *OCF* and *OAF* as θ, γ, δ and ε respectively.

With the ratios a/l and b/l defined as k and k_1, the cosine rule may be applied to give the following relations:

$$m = l\sqrt{1+k^2-2k\cos(\alpha-\theta)} \quad . \quad . \quad . \quad . \quad (1)$$

$$n = l\sqrt{k^2+k_1^2-2kk_1\cos(\alpha-\beta-\theta)} \quad . \quad (2)$$

Thus,

$$y = l\sin\theta + m + 2n - s$$

$$= l\{\sin\theta + \sqrt{1+k^2-2k\cos(\alpha-\theta)} + 2\sqrt{k^2+k_1^2-2kk_1\cos(\alpha-\beta-\theta)}\} - s$$

$$. \quad . \quad . \quad . \quad . \quad . \quad (3)$$

It is therefore apparent, from the form of this expression, that no set of values for k, k_1, α and β will give a constant y against a variable θ.

The condition for level-luffing may also be written as $dy/d\theta = 0$, that is

$$\cos\theta - \frac{lk}{m}\sin(\alpha-\theta) - \frac{2kk_1l}{n}\sin(\alpha-\beta-\theta) = 0$$

$$. \quad . \quad . \quad . \quad . \quad . \quad (4)$$

This equation may also be obtained from the condition that the sum of the moments of the forces due to the load W should be zero about the jib pivot O. This requires that

$$W(\cos\theta - \sin\gamma\,\frac{2z}{l}\sin\delta) = 0 \quad . \quad . \quad (5)$$

where $z = OC$ in Fig. 2.

But, from the sine rule,

$$\frac{\sin\gamma}{a} = \frac{\sin(\alpha-\theta)}{m} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$$\frac{\sin\delta}{b} = \frac{\sin\varepsilon}{z} = \frac{a}{zn}\sin(\alpha-\beta-\theta) \quad . \quad (7)$$

Thus, in equation (5),

$$W\left(\cos\theta - \frac{a}{m}\sin(\alpha-\theta) - \frac{2z}{l}\cdot\frac{ab}{zn}\sin(\alpha-\beta-\theta) = 0\right)$$

which may be expressed as equation (4).

If the load path is not exactly horizontal then the equation of work gives the moment about the jib pivot as

$$T_0 \times \delta\theta = W \times dy$$

Thus,

$$T_0 = W\frac{dy}{d\theta} \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

This same expression follows from equation (5), since when level-luffing does not actually occur the terms within the brackets evidently represent a lever arm which has been shown to equal $dy/d\theta$.

This moment about the jib pivot is simply related to the torque on the luffing shaft, T_l, since

$$T_0\delta\theta = T_l \cdot \delta\phi,$$

that is,

$$T_l = T_0\frac{d\theta}{d\phi} = f \cdot T_0 \quad . \quad . \quad . \quad . \quad (9)$$

where ϕ is the angle of rotation of the luffing shaft.

The ratio of the angle changes of the jib and the luffing shaft, $f = d\theta/d\phi$, can be determined by use of the instantaneous centre of rotation of the connecting rod between the jib and the end of the crank arm attached to the luffing shaft. An expression could have been derived for this from the co-ordinates of the crank shaft and the jib pivot and from other relevant dimensions on the cranes. However, curves of f against θ between maximum and minimum angles of inclination θ_1 and θ_2 were supplied to the authors, and it was found that the empirical expression:

$$f = c(\theta_2-\theta_1)\left[1 - 16\left(\frac{\theta - \left(\frac{\theta_1+\theta_2}{2}\right)}{\theta_2-\theta_1}\right)^4\right] \quad . \quad (10)$$

c being a constant,

fitted this curve remarkably well. To avoid delay at the time, this f-θ variation was

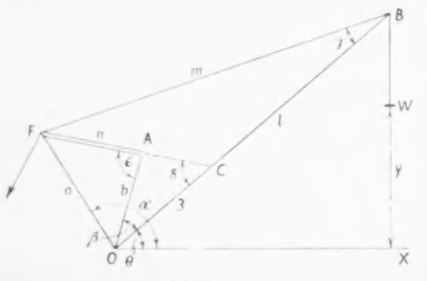


Fig. 2

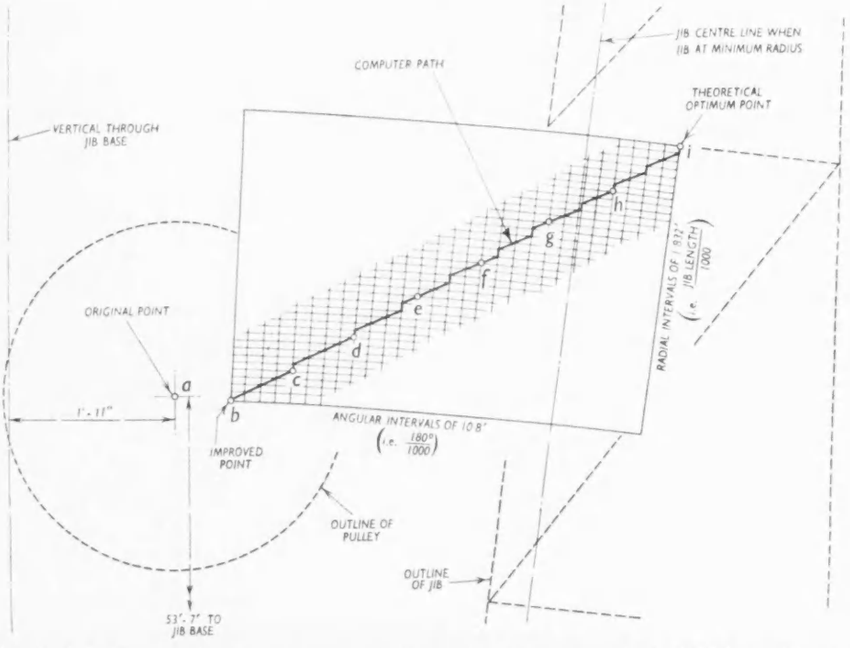


Fig. 3—Path followed by the electronic computer in finding the optimum position for the "A" frame pulley on a Clyde crane

adopted for the luffing shaft torque calculations.

Programming a Computer Search for Optimum Pulley Positions

The particular case of the 1 : 1 Mannock level-luffing arrangement will be discussed first. This level-luffing mechanism is used on the 7½-ton Clyde grabbing crane, and the makers, Clyde Crane and Booth, Ltd., very kindly supplied drawings to enable the authors to proceed with this investigation. The existing position of the fixed pulley at the top of the "A" frame had already been slightly altered at the time, so this improved position was used as a starting point for the search for any theoretical improvements.

For this type of crane the general theory derived above can be considerably simplified, since pulleys A and F are coincident. Thus the load path is given by the expression

$$y = l\left\{\sin\theta - \sqrt{1 + k^2 - 2k\cos(\alpha - \theta)}\right\} - s \quad . \quad . \quad . \quad . \quad . \quad (11)$$

and the luffing shaft torque is given by

$$T_l = f\left\{\cos\theta - \frac{k\sin(\alpha - \theta)}{\sqrt{1 + k^2 - 2k\cos(\alpha - \theta)}}\right\} \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Now though it is clear that any alteration in the fixed pulley position, to reduce the variation in the height of the load path, will also tend to reduce the range of the torque in the luffing shaft, it is not apparent that these two conditions will necessarily require the same optimum pulley position. In view of this uncertainty it was decided to find the position of the fixed pulley to minimise the torque range (it so happened that this position also gave the load path with the least vertical movement).

A programme was prepared for the Ferranti Pegasus computer, to calculate T_l from equation (12), using the expression for f in equation (10), with an appropriate value for the constant c. The luffing shaft torque was calculated at the extreme θ_1 and θ_2 inclinations of the jib, and at nine equally spaced intermediate θ values. These T_l values were stored and the maximum torque range calculated from them.

The problem of moving the fixed pulley, F, to give a reduction in this torque range was easily solved by use of a "floating" polar mesh. The pulley was considered to lie at the centre of a nine-point grid defined by three radial lines $(\theta - \delta\theta)$, θ, $(\theta + \delta\theta)$, and by three circular arcs at $(r - \delta r)$, r, $(r + \delta r)$. These grid points were identified by means of references 0, 1, and 2; thus the point $(\theta - \delta\theta)$, $(r - \delta r)$ was written as 0, 0; and the pulley position as 1, 1. The computer programme was arranged so that the torque range could be calculated for the "A" frame pulley at each of these grid points, then these torque range values were compared and the smallest selected. The polar mesh was then moved to lie centrally over the improved position and the procedure repeated. The programme was arranged to print out the co-ordinates and the torque range corresponding to each improved pulley position, and to stop when it was found that none of the surrounding grid-points corresponded to a reduced torque range.

The path taken by the computer during its search is shown in Fig. 3, where the extreme inward position of the jib is also shown in relation to the fixed "A" frame pulley positions. The torque variations for this fixed pulley at the initial and improved positions used by the makers, and at the theoretical optimum pulley position, are plotted in Fig. 4 (*a*), and the corresponding load paths are drawn in Fig. 4 (*b*).

It is seen that the torque range in the luffing shaft, and the vertical "wander" of the load path, can be reduced theoretically to about two-thirds of their values at the starting point for the computer search.

Further Applications

This computer search technique was easily extended to "hunt" for improved pulley positions in the Smith-Walls mechanism. Two separate polar meshes were required, one for the pulley at the top of the "A" frame and the other for the pulley at the back of the jib, towards the jib pivot. Again nine grid points were possible, on each mesh; this meant eighty-one separate calculations for torque range at each stage, and a consequent shift of the pulleys to the two points giving the lowest value. It was found that the calculations could be organised differently inside the computer to give maximum computing speed. As before, the new positions of the pulleys and the torque range were pointed out at each stage; this time four numbers served to identify any two pulley positions with 1, 1 ; 1, 1 representing the central grid points. The computer was arranged to stop when these same points 1, 1 ; 1, 1 were selected for the next move.

Separate calculations were required for cranes with different extreme θ_1 and θ_2 jib inclinations, but a representative case is shown in Fig. 5, where the corresponding pulley positions are shown numbered at each stage of the search. Occasionally, only one of the pulleys was required to move, and a reversal actually occurred at one stage, but on the whole a definite trend was revealed,

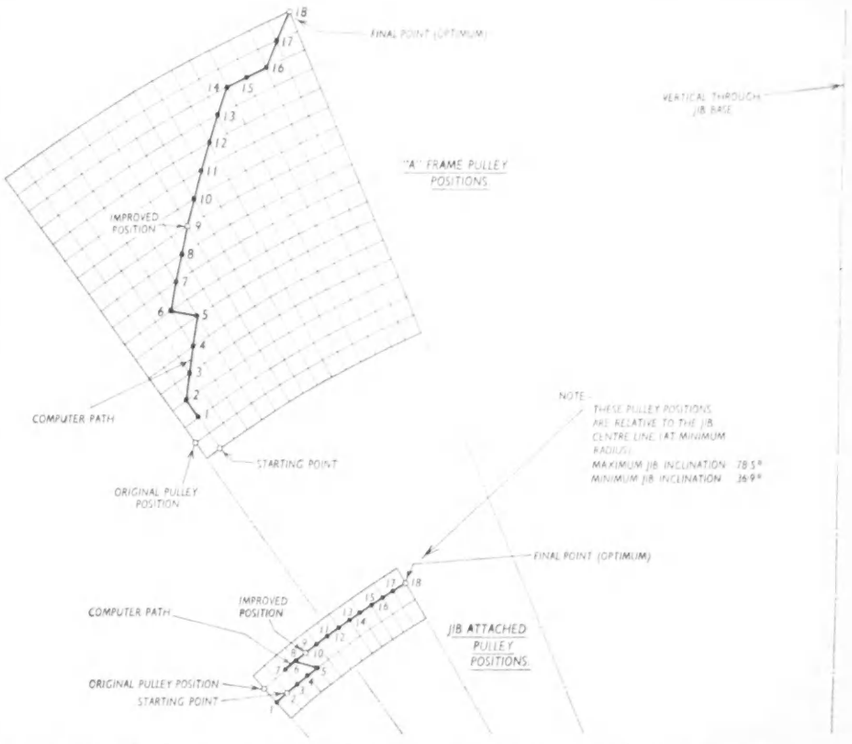


Fig. 5—Paths followed by electronic computer in finding optimum positions for the "A" frame and lower jib-attached pulleys, on a Smith-Walls crane

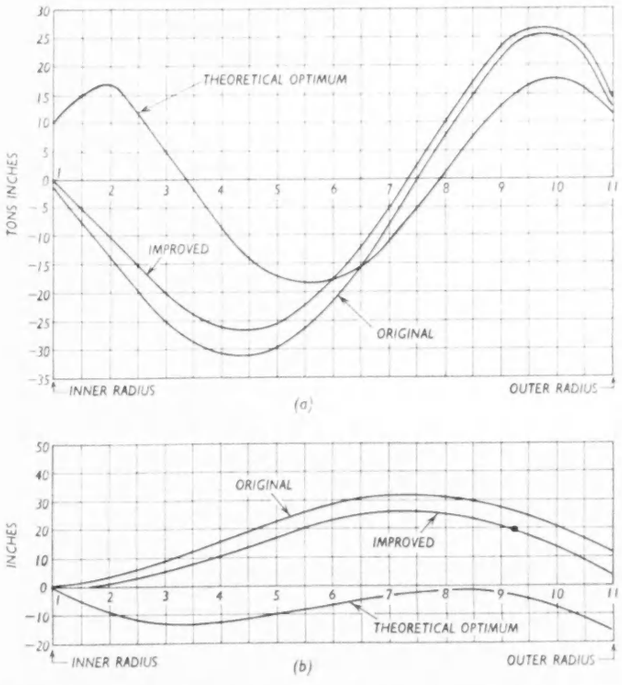


Fig. 4 (*a*)—Variation in static torque on the luffing shaft, and (*b*)—Variation in the vertical position of the load, between minimum and maximum radii of operation, for the Clyde crane investigated, for different "A" frame pulley positions

the "A" frame pulley moving mainly upwards and slightly inwards towards the vertical axis of the crane, and the lower jib pulley moving in towards the jib at an approximately constant radius.

For the case illustrated by Fig. 5 the torque variations for the initial and theoretical optimum pulley positions are plotted in Fig. 6 (*a*). The variations in the load path during luffing are also shown in Fig. 6 (*b*) for these same two sets of pulley positions. It will be observed that a theoretical reduction of about 50 per cent is possible in both the torque range and the vertical "wander," but these cannot usually be realised because of conflicting design considerations (which are mentioned below).

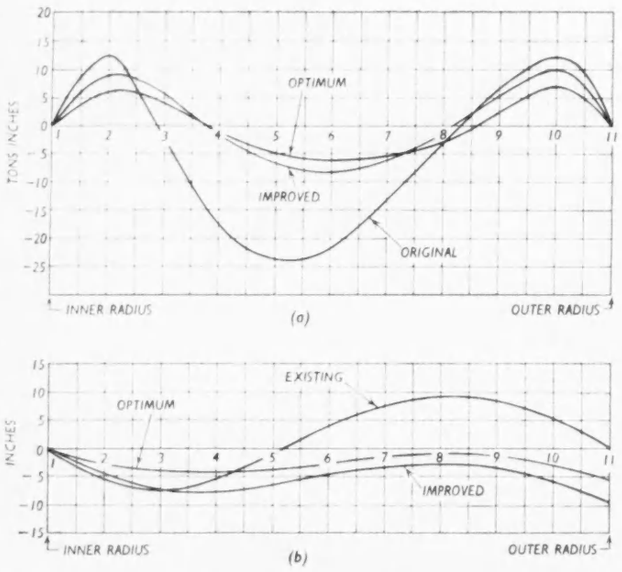


Fig. 6—(*a*) Variation in static torque on the luffing shaft, and (*b*) Variation in the vertical position of the load, between minimum and maximum radii of operation, for the Smith-Walls crane investigated, for different pairs of pulley positions

Practical Limitations

In Fig. 3 the optimum pulley position is seen to fall inside the jib at its minimum radius. Now it may be possible to allow the pulley to enter the jib partially at this extreme inclination, provided the bracing is rearranged to avoid fouling and the rope remains clear of the jib. But a certain amount of clearance is usually considered desirable, so some compromise solution is therefore adopted in such circumstances. For the Smith-Walls type of mechanism there is little possibility, in practice, of the "A" frame and lower jib pulleys fouling at the maximum jib inclination at minimum radius, but this is another point which is always checked by the crane designer. With such clearance and other design requirements considered along with this information from the electronic computer the designer is able to take the best advantage of these interesting level-luffing mechanisms.

The problem of the structural design of the jibs of cargo cranes is of major importance and these various mechanisms all result in different loading conditions. The behaviour of these jibs and their luffing mechanisms under the various normal and accidental dynamic conditions encountered during operation is also of relevance. These dynamic effects assume increasing importance with the demand for higher luffing speeds in modern cargo cranes.

As luffing speeds are increased a desirable feature of the load path is that it should rise at the ends so that the kinetic energy of the jib can be automatically absorbed in lifting the load at the ends of its radial travel. It will be seen from Fig. 4 and Fig. 6, however, that this condition would require different pulley positions from those needed for minimum luffing shaft torque and vertical "wander" of the load in luffing. It might not, in fact, be possible to achieve this automatic braking at the maximum radius of operation simply by altering pulley positions. The criteria adopted in this paper remain unchallenged, however, for cranes with normal luffing speeds.

These various practical points have been mentioned as important factors which must also be considered. Nevertheless, this theoretical study has already contributed to improved crane design, for the computer paths shown in Fig. 3 and Fig. 5 give valuable guidance to the designer.

Conclusions

The electronic computer can be very usefully applied to determine, theoretically, the best positions for the pulleys of certain types of cargo crane. The basis adopted for this selection of pulley positions is that the static torque range in the luffing shaft should be a minimum; this criterion also gives (or almost gives) a minimum vertical "wander" of the load during the luffing motion.

The luffing shaft torque variation may be altered by adjusting the balance weights attached to the jib, but only to a limited extent, since a jib frequently has to be luffed without any hook or grab load. The easiest overall procedure is to minimise the torque range for a balanced jib as explained in this paper, allowing for practical considerations, and then to take advantage of any improvements that might be obtained from an adjustment of the balance weights.

For given minimum and maximum jib inclinations there appear to be unique optimum pulley positions, relative to the jib length as the unit dimension, for both the Toplis and Mannock mechanisms. The Smith-Walls mechanism is a more complex geometrical problem, though the rope reeving is still quite simple. It seems likely, however, that the practicable areas for the pulley positions for this type of crane have already been covered in this computer investigation; nevertheless, it is conceivable that other possible solutions might exist.

Finally, it is recognised that many other design requirements have to be considered in the design of the jibs and the luffing mechanisms of electric cargo cranes, so this computer work is a contribution, rather than the entire answer, to improved design.

Acknowledgments

The authors are greatly indebted to the managing directors and the chief designers of the following crane firms for their interest and assistance in this electronic computer investigation: Clyde Crane and Booth, Ltd., Mossend, Glasgow, and Rodley, Leeds; Thomas Smith and Co., Ltd., Rodley, Leeds; Stothert and Pitt, Ltd., Bath. The calculations were performed in the University of Leeds Computing Laboratory and the authors are very grateful for the assistance they received there.

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Mechanical Handling Exhibition

THE Mechanical Handling Exhibition which opens at Earls Court, London, on Tuesday next, May 3, will be the largest and most comprehensive display of handling equipment ever staged in this country. The stands of the exhibitors will cover an area of over 500,000 square feet, and almost every firm represented will show typical equipment in actual operation or in animated model form. To provide facilities for manufacturers of some of the larger handling installations too big and complicated to exhibit at Earls Court, a special symposium of films is being arranged to show the industrial application of heavy plant. Preliminary information which has come to hand indicates that there is now available in this country plant to cover the handling requirements of practically every class of product in bulk or packaged form and for its storage, sorting, transport and weighing by automatic or manually controlled means.

There still remain in all branches of industry many manual handling jobs which could be more economically effected with machines, and it is in a visit to an exhibition of this kind that such jobs come to mind on seeing the latest designs of plant which are available. Indeed, for concerns where marginal savings, possible in more efficient handling, could prove an important economic factor, this exhibition provides a valuable facility for inspecting newly developed plant, comparing the designs of different makers and discussing problems with specialists in handling. Although at first glance by those who have visited previous exhibitions, there may seem to be few outstandingly new pieces of equipment or revolutionary new handling systems, they will, on closer inspection, find interesting improvements in detail and automatic controls. It will also be noted that the trend continues towards simplifying manual operation, higher working speeds, and unit design with ease of access to facilitate maintenance.

As in previous years, the jibs of cranes towering above the stands in Earls Court will provide a striking background. In this connection it will again be noted that, although makers in this country offer an unrivalled selection of cranes of all kinds, no attempt seems to have yet been made to introduce a British tower crane of the type so widely used in the building industry. Certainly, numerous types of these tower cranes of Continental design are being made under licence and sold by British firms, but we know of none of all-British design and manufacture. With the experience of crane design available in this country and the extensive demand brought about by the increasing use of tower cranes in building, it is somewhat surprising that British manufacturers have not made greater efforts to satisfy and secure what has proved to be a healthy home market.

A new mobile crane being made by Ransomes and Rapier, Ltd., Ipswich, shown in Fig. 1, is designed for working loads of 15 tons at 10ft radius when propped or 8 tons free on wheels. When fitted with a 30ft strut jib or a 20ft cantilever jib, these loads can be raised to a height of 30ft and alternative extendible strut jibs from 30ft to 80ft long are available with this crane. The machine has a turning circle of 21ft 6in and compressed air power assisted steering reduces operator fatigue. When fitted with pneumatic tyres, the crane has a road speed of 6 m.p.h.

The group of self-propelled diesel-electric "Coles" cranes shown by Steels Engineering Products, Ltd., Crane Works, Sunderland, will include the recently introduced "Dominant" wide chassis crane (Fig. 2). It has a maximum lifting capacity of 12½ tons at 10ft radius when fitted with a 30ft centres strut jib and with stabilising jacks extended. It will also lift 9 long tons in a fully mobile condition. The crane being exhibited is fitted with a 50ft strut jib comprised of two basic 15ft sections and a 20ft extension piece. With the use of such extension pieces it is possible to lengthen a jib on this crane to a maximum of 80ft. Of interest on this crane is the equipment designed to allow the use of an electromagnet. A booster generator is fitted with automatic voltage control, and the magnet control gear is installed in the driver's cab. For this gear a spring-loaded, combined cable reeling drum and tag line is fitted on the jib and the crane on show will be fitted with a 40in, 220V d.c. electromagnet. A self-propelled diesel-mechanical crane with a hydraulically-operated cantilever jib and capable of lifting 6 long tons at 10ft radius on a 25ft centres jib will be exhibited by R. H. Neal and Co., Ltd., of Grantham. On this crane the derricking motion is operated by two hydraulic triple-extension rams, and a hydraulic lock ensures that the jib is safely supported at all times.

Fig. 1—Mobile crane with 30ft strut jib and a lifting capacity of 15 tons at 10ft radius propped or 8 tons free on wheels—Ransomes and Rapier

Fig. 2—Wide chassis "Dominant" mobile diesel-electric crane with a maximum capacity of 12½ tons at 10ft radius—Steels Engineering

The 2-ton capacity at 6ft 9in radius full circle slewing, truck-mounted crane made by Tunny Cranes, Ltd., 2, Victoria Street, London, S.W.1, is designed for road travelling at 30 m.p.h. On this crane, shown in Fig. 3, all of the motions are hydraulically operated, power being provided by a pump driven from the engine power take-off. Hoisting at speeds up to 60ft per minute is effected through a six-sheave pulley system from a hydraulic cylinder and lowering is controlled under power. Other hydraulic cylinders derrick the jib over its full range in twenty seconds, and slew the crane through a full circle at 2½ r.p.m.

Supplementing a group of the well-known Jones cranes on the stand of the George Cohen 600 Group, Ltd., Wood Lane, London, W.12, there will be a sectionalised model of the K.L.33 mobile crane to show the firm's system of direct mechanical transmission from the engine to all the crane motions. This firm is also showing its 1-ton and 2-ton capacity lorry loaders, which can be fitted to any load-carrying vehicle of 5 tons capacity or over. These loaders, which are hydraulically operated by a pump driven from the engine power take-off, are centrally mounted and provided with dual control positions on each side of a vehicle. The telescopic boom fitted to the loader

Fig. 3—2-ton truck-mounted crane with hydraulically operated motions—Tunny

enables the whole load area of the vehicle to be covered and can also be used for simple erection and similar duties adjacent to the side of the truck.

An overhead crane system now being made by British MonoRail, Ltd., Brighouse, Yorks, is designed to occupy the minimum amount of headroom for installation in existing buildings without need for major structural changes. An installation consists of two or more parallel runways which can be attached to convenient roof members covering the length of the area it is desired to serve. The width between the runways is spanned by a bridge attached to trolleys running on the lower flanges of the runways. This bridge can be up to 200ft long and carries crane hoists of up to 5 tons capacity on trolleys running along the bridge rail. The cranes are fully motorised, and longitudinal movement of a load is achieved by moving the bridge along the runways, while for transverse travel the hoist is driven along the bridge rail.

In cases where loads need to be transferred from one bay to another, loaded hoists may be traversed between bridges in adjacent bays across interlocking transfer sections. To provide additional flexibility of handling, a number of bridges may be installed on the same runways. In some cases it may be desirable to have two or more separate bridges in the same bay and, where these run parallel to each other, they can be interlocked when it is necessary for loads to traverse the full span.

In addition to typical examples of conveyor installations for large and complex manufacturing processes, Geo. W. King, Ltd., Stevenage, Herts, is showing a light " Dual-Duty " overhead conveyor arranged for fully automatic operation incorporating the firm's system of indexers. With this conveyor the load trolleys are propelled by the moving chain although not attached to it. Using switch wheel corners, individual loads or a number of loads may be automatically switched from one conveyor to another, and stopped at specified stations on any conveyor without stopping the chain or the movements of loads elsewhere on the system.

A new item being displayed for the first time will be the King " My-te-Min " Mark II electric chain pulley block which is made in four sizes of from ¼-ton to 1½-ton capacity. This block incorporates electro-magnetic disc brakes, automatic chain guards and a new push-button control.

The usual widely representative selection of belt, slat, bucket, pallet, roller and other forms of conveyors will be shown, and several manufacturers have again designed ingenious closed circuits of different designs of conveyors and elevators to demonstrate their versatility and speed in handling goods of various kinds. Mobile, portable, extending and sectionalised conveying equipment is being adopted to an ever increasing degree in all branches of industry, and the exhibits will include many examples of general and special purpose units. A conveyor idler to be exhibited for the first time is the " Camberoller " of West's Gas Improvement Company, Ltd., Miles Platting, Manchester, 10, which is designed to provide a self-lubricating, easily replaceable unit of semi-rigid but impact resistant nature. The unit, to be seen in Fig. 4, consists of hard rubber rollers equipped with bonded mild steel journal bearings mounted on independent oil-impregnated sintered bronze bearings, secured to a curved mild steel idler spindle. Bearing protection is arranged at the outer ends and between the inner rollers, and the oil-retaining

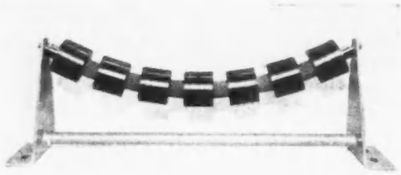


Fig. 4—Self-lubricating band conveyor troughing idler—West's Gas Improvement

bearings contain approximately 30 per cent of oil by volume within their porous structure. The sealing units are packed with a molybdenum disulphide compound and the idler spindle is inclined so that the plane of action of the outer rollers converges, thus assisting accurate belt tracking.

A lip bucket conveyor, to be shown by the firm, is available with buckets of the conventional lipped type in both mild steel and aluminium. The forged steel chain links are fitted with case-hardened bushes on which rotate high-grade cast iron runner wheels. Rolling motion occurs only at the bushes while the axle turns only at conveyor directional changes. Relative movement of the axle and links is prevented by the anchorage of the outer links to the axle extremity and the mounting of the inner links on the spigotted bushes. In this way wearing components are reduced to a minimum.

The principal exhibit of Richard Sutcliffe, Ltd., Horbury, will be a conveyor circuit consisting of two main conveyors, one electrically and the other hydraulically-driven. Included in the circuit, which will be handling washed granite chippings, is a short cross conveyor, a chute, belt weighers and a batch weigh hopper. The circuit will be used to demonstrate the latest methods of measurement and control by the application of hydraulic and electronic equipment. The speed of the hydraulically-driven conveyor will be controlled through a variable speed hydraulic pump, and the measuring devices will record such information as the conveyor speeds, the weight of material in the batch hopper at any time, the total weight of material handled by the circuit, the rate of flow, &c.

A multi-blade conveyor belt scraper, to be shown on this firm's stand, has a series of 6in wide blades with wear-resistant rubber bonded on the leading faces to a height of 2in. Each blade is supported at right angles to the carrying surface of the belt by a spring steel bar parallel to the centre line of the conveyor and carried at the opposite end by a cross shaft located on the two side frames. By mounting these bars at a pitch slightly greater than the width of each blade, using alternate bars of different lengths, it is possible to have two sets of blades across the width of the conveyor, continuous in each case except for short spaces through which the bar in the alternate line passes. The mounting of each blade on an individual spring steel bar allows a blade to wear down individually, according to the amount of work it does, and no part of the belt is left unscraped.

A motorised drum suitable for conveyor and elevator drives is made by the Richards Structural Steel Company, Ltd., Leicester, in a number of sizes from ¼ h.p. to 15 h.p. with output torques from 65 lb to 1465 lb ft. These drives comprise a three-phase stator rotor built within, and coupled by an epicyclic gear train to, a conveyor head drum. The drum shell is crowned and its end housings form an oil-tight chamber for lubricant, which circulates freely through the spaces in the motor unit and the gears. This oil, in addition to providing a lubricant for the gears and bearings, also acts as a coolant for the motor, the windings of which are coated by epoxy resin. If required, the units can be provided with electro-magnetic brakes or backstop devices.

A mechanical vibrating feeder made by Vimec Equipment, Ltd. (Lockers (Engineers), Ltd.), Church Street, Warrington, and known as the " Locker Amplitrol " has a simple drive consisting of an a.c. motor mounted between two banks of heavy-duty pneumatic springs. An offset weight on the motor shaft generates a small centrifugal force which is amplified by the pneumatic springs to vibrate the trough. Required capacity or amplitude changes are made by simply varying the air pressure in the springs either manually or by automatic means. The makers state that, operating at natural

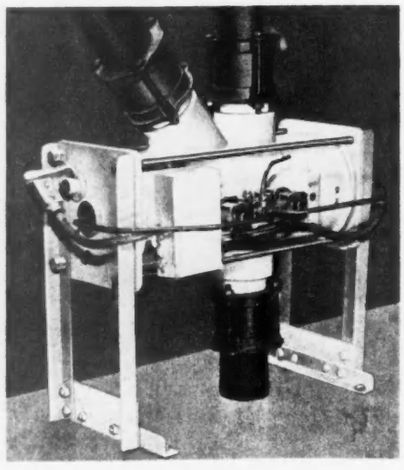


Fig. 5—Electrically controlled electro-pneumatic diverter valve—Thomas Robinson and Son, Ltd.

frequency, the pneumatic springs supply up to 90 per cent of the force needed for operating the feeder.

A working pneumatic conveying plant, electronically controlled and incorporating electrical weighing equipment, will be the main exhibit on the stand of Thomas Robinson and Son, Ltd., of Rochdale.

This exhibit has been compactly designed to give a practical demonstration of the firm's "Pneu-Flow" pressure conveying system, coupled with a modern control system, and batch weighing using weigh bins mounted on electrical load cells. The electronic controls and load cells incorporated in the system are products of Elliott Brothers (London), Ltd.

The system, used for the bulk handling of powdered and granular products, incorporates a blower which provides the conveying air stream in a small diameter conveying pipeline. Stock is fed into the pipeline through air seal rotary feeders and the stream of material can be diverted to any number of required points by air-energised two-way valves, electronically operated from a remote panel; one of these valves is shown in Fig. 5. Batches are weighed in a bin mounted on load cells, and in the case of the exhibit the precise weight required is selected and indicated on a dial in the centre of the equipment.

A new 6000 lb at 24in fork truck which has been introduced by Conveyancer Fork Trucks, Ltd., of Warrington, is based upon the "T.C." series 3 trucks, but has specially designed bodywork and a power train of unit construction which facilitates overhaul and maintenance. In this new fork truck, to be seen in Fig. 6, the top bodywork cover is hinged so that it can be lifted for general servicing of the engine, battery, fuel system and radiator. If required the engine can be removed separately or as a single unit with the torque-converter/gearbox. After the removal of the mast, which pivots on the driving axle, the complete transmission can be taken out in one piece or the differential assembly serviced without removal of the complete driving axle.

With this hydro-kinetic transmission these trucks are controlled by a footbrake and accelerator pedals only—clutch pedal and gear shift being eliminated. A simple direction selector replaces the gear lever and when pushed to the "forwards" or "backwards" position the drive is automatic with operation of the accelerator.

Power developed by the engine is transferred to the driving axle by the vortex circulation of oil between an engine-driven impeller and a turbine. A reacti on member fitted between the impeller and the turbine allows torque conversion action totake place during the initial accelerating period. As the truck gains speed the torque multiplication falls off until a speed is reached where the reaction member commences to freewheel and the unit operates as a fluid coupling.

The epicyclic gearbox provides reversal of final drive and simultaneously gives a further speed reduction. The band brakes are operated by fluid pressure generated by an integral gear pump driven by the impeller through an intermediate gear. A monitored direction selector valve which controls the oil flow to the brake bands is operated mechanically by the direction selector linkage. This valve prevents the opposite traction selection being made when the engine is running quickly and thus, by eliminating use of the torque converter as a brake, safeguards the transmission from misuse.

British Electrical Repairs, Ltd., of Manchester, manufacturers of a wide range of lifting tackle, will show amongst a number of recent developments an internal expanding device for lifting paper reels from both

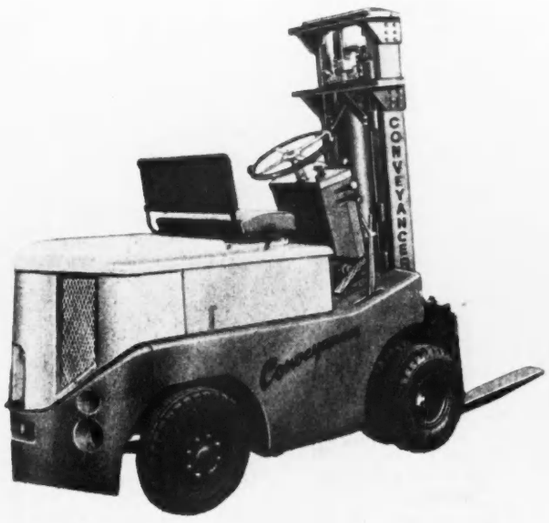


Fig. 6—Fluid-drive 6000 lb fork truck with power train of unit construction to facilitate servicing—Conveyancer Fork Trucks

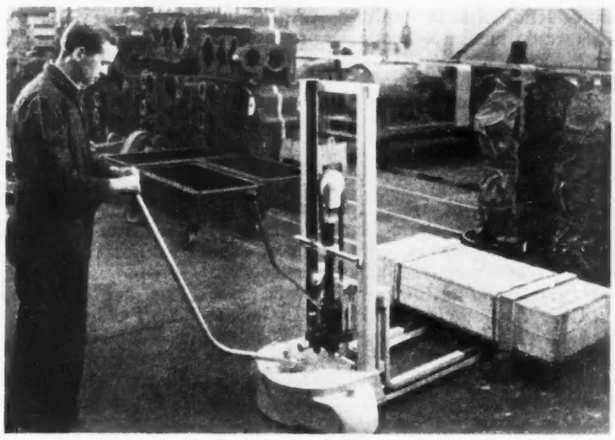


Fig. 8—Pedestrian controlled fork lift truck—Sheepbridge Equipment

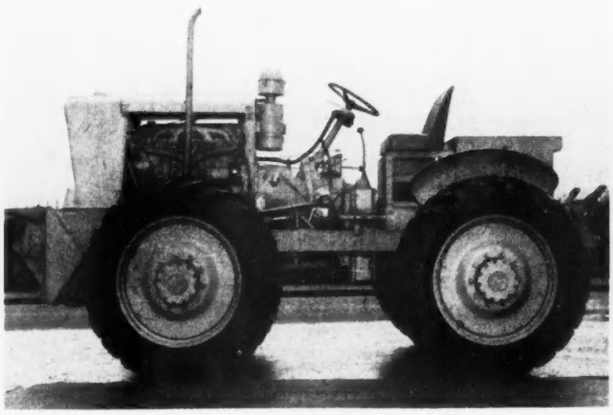


Fig. 7—96 h.p. heavy duty tractor—Bray Construction

Fig. 9—"Dempster-Dumper" vehicle dumping a 3 cubic yard container —Powell Duffryn

vertical and horizontal positions. This device is suspended from a crane hook and inserted into the central hole of the paper reel. A catch is operated manually, and when the crane hook is then raised the device expands and grips the core of the reel. The device, which is automatically released by a slight overlowering of the crane hook, accepts 15-cwt reels, but larger units can be supplied for lifting reels of up to 2½ tons.

A number of versatile pedestrian-controlled lifting equipments and fork lift trucks have been developed to speed and reduce manual effort in handling goods in small establishments or in departments where the introduction of larger power-operated machines would not be an economic proposition. One such fork lift truck is that made by Sheepbridge Equipment, Ltd., of Chesterfield, which is shown in Fig. 8. This machine has a fixed mast and is designed to lift loads of 4 cwt to a height of just under 7ft on its 19in long forks. In their lowest position the forks are only 5in above ground level so that the truck forward support extension can be introduced under loads set at a reasonable height on the floor. The overall fork width is adjustable between 18in and 4in on the lifting frame of the mast.

The fork frame is guided by rollers in the vertical channel-section mast and is raised through a roller chain gearing by a hydraulic ram. A two-speed hand-operated hydraulic pump is designed to enable loads of 4 cwt to be raised at a speed of 1½in per double stroke or up to 3 cwt 2½in per double stroke. A fingertip operated control gives variable speed lowering with immediate stopping of the forks at any required height. The hinged towing handle is also used for steering the truck.

A heavy-duty tractor, the "Centaur," developed by the Bray Construction Equipment Company, Ltd., Feltham, Middlesex, and illustrated in Fig. 7, is exhibited for the first time by the makers as a ploughing unit. As with the industrial version, the tractor has a four-wheel drive and is powered by a Ford six-cylinder oil engine of 96 h.p. With its drawbar pull of over 12,000 lb the machine can be used as a ploughing tractor, fitted with a five-furrow plough at each end for one-way ploughing duties. A British three-point linkage at each end is designed to accommodate any standard agricultural implement, including a heavy tool bar to take a nine-tine cultivator.

These tractors are provided with heavy-duty axles with planetary hub reduction gearing and hydraulic braking on all four wheels. Power-assisted steering considerably reduces driver fatigue on heavy ground and when arduous operating conditions are encountered.

One of the 702 industrial tractors made by Massey Ferguson, of Coventry, is to be shown fitted with a front-mounted shovel and a rear-mounted digger. This tractor is powered by a 37 b.h.p. diesel engine and power for operating the digger and shovel is provided by a hydraulic pump driven from the front end of the engine crankshaft. The shovel, when fitted with a standard bucket, can raise and tip up to 2000 lb of granular material at a height of 8ft 6in. In addition to the shovel there can be fitted to the tractor front a scarifier, an angledozer, a jib and a fork lift. The digger at the rear is operated from a rearwards facing seat and is designed to work down to a depth of 12ft and discharge to a height of 10ft. It has a 200 deg. operating arc and can be fitted with buckets from 12in to 36in wide.

Two examples of the "Dempster-Dumpster" mechanised equipment for handling bulk materials are to be shown by the Powell Duffryn Engineering Company, Ltd., Cardiff, which is now making the equipment under licence in this country. A standard vehicle chassis used in this system of bulk handling is equipped with the means of self-loading and tipping containers of various types specially devised to carry the required materials. By using a number of these containers waiting time by vehicles and drivers is largely eliminated. With the equipment available containers of from 1 to 15 cubic yards capacity can be lifted to a dumping height of 10ft or automatically self-loaded into compaction bodies of 18, 24 or 30 cubic yards capacity. With hydraulic power one vehicle can pick up or set down its own body of up to 40 cubic yards capacity.

We illustrate in Fig. 9, one of the "Dumpster" vehicles which will lift, transport and dump or set down containers of 1 to 15 cubic yards capacity. The only manual effort required with this vehicle is the attachment of the conveyor chain slings; thereafter all operations are mechanically controlled from the driver's cab. Another vehicle shown, the "Dinosaur," can, using its own hydraulically-powered equipment, pick up from ground level and put down its container body in either a loaded or unloaded condition. It is available with bodies to take from 10 to 40 cubic yards of material and weighing up to 30,000 lb.

In addition to a self-contained hydraulically operated table for handling components on machine lines or serving as elevating platforms for loading vehicles and similar work, Access Equipment, Ltd., Maylands Avenue, Hemel Hempstead, will show a suspended powered platform known as the "Wall Spider." This working platform, which can be slung down the side of a building or other high structure by steel ropes, is raised and lowered by a 2 h.p. motor incorporating automatic braking and limit switches. It has a 6ft by 2ft 3in platform enclosed by guard rails and is capable of supporting a 500 lb load—equivalent to two men with their painting equipment or tools. Fully loaded, the hoisting and lowering speed is 40ft per minute and the standard rope drum takes 150ft of cable.

In view of the car parking problems now experienced in large cities, the "Parcar" mechanical car park developed by Mitchell Engineering, Ltd., Peterborough, is of particular interest. This garage consists of a series of floors arranged on each side of a central well or corridor along which there travels a tower crane carrying a car lift platform and its associated equipment. As the car lift can be moved vertically and the tower traversed along the line of parking floors, a direct route is available to any parking bay by a combination of movements to introduce or remove a car in the minimum time. The lift platform incorporates a mechanical "dolly" which introduces a car on to the platform or takes it off. According to the required capacity of a car park, its height and rate at which it is needed to handle the vehicles, one or more lift towers can be provided, or lifts capable of carrying more than one car installed.

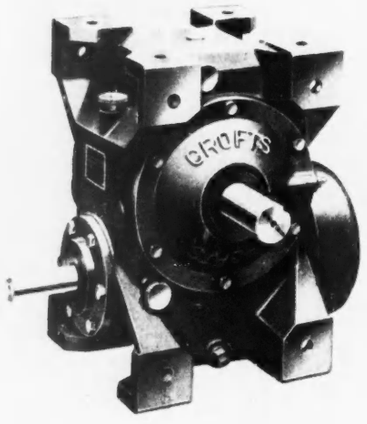


Fig. 11—Universal mounting, single reduction worm gear—Crofts

The range of "Self-Lube," self-lubricating self-sealing, self-aligning ball bearing pillow blocks and bearings will comprise one of the main displays on the stand of Pollard Bearings, Ltd., Knottingley, Yorks. These units consist of a self-aligning ball bearing, capable of withstanding both radial and thrust loading, mounted in a housing which can be easily fitted to any piece of equipment. Each unit is filled during manufacture with grease and sealed for life by a dual seal.

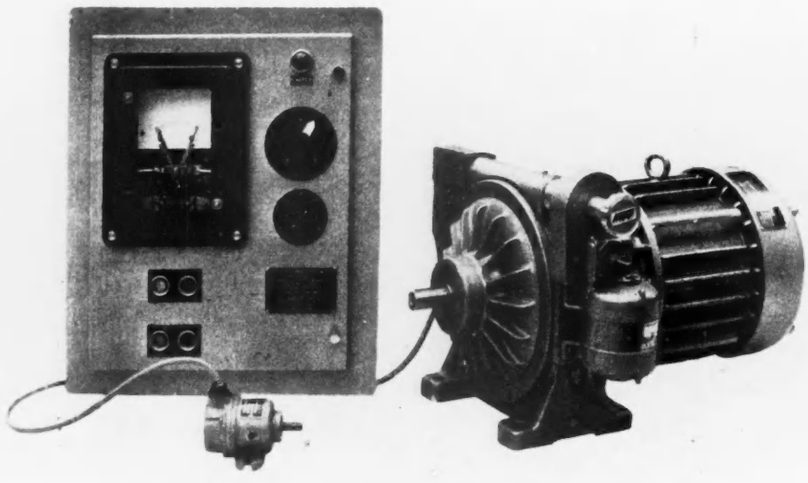


Fig. 10—Speed corrector unit coupled to variable speed gear drive—Allspeeds

The efficiency of the sealing system incorporated in the bearings will be demonstrated on the stand by a test rig in which a number of "Self-Lube" units operate in simulated desert sand-storm conditions. A second test rig will be used to demonstrate various applications of the range, which can be supplied to suit shaft sizes from ½in to 6in diameter in many forms.

New products shown by the Plessey Company, Ltd., Ilford, Essex, will include a reversible gear-type hydraulic motor with a high starting torque. This motor is rated at 5 h.p. at 1500 lb per square inch and 1500 r.p.m., and it is capable of speeds up to 3000 r.p.m. A new relief valve has been designed to provide a compact pilot-operated relief unit to accommodate flows up to 10 gallons per minute at pressures up to 3000 lb per square inch. A feature of this valve is its flat characteristic over a wide flow range.

Reduction gear units available in the "Par-O-Mount" series made by Crofts (Engineers), Ltd., Thornbury, Bradford, are adaptable for a variety of mounting positions, shaft dispositions and ratios of speed reductions. They are made as single reduction worm gears and single reduction helical gears, their cases having integral feet machined and drilled on all faces to facilitate different mountings. The worm gear case, see Fig. 11, is of one-piece construction and the single helical gear case is made in two halves bolted together. Seven sizes of worm gear units with up to 5in centres handle from fractional horsepowers up to 25 h.p., in stock ratios from 5 to 1 to 70 to 1. The single helical gears are available for from 3in to 10in centres, powers up to 600 h.p. and in standard ratios up to 6 to 1.

Another recent Croft product is the "Autojust" series of magnetic clutches and brakes specially developed for machine tool gearboxes. These units are made in thirteen models, covering up to 45 h.p., and once installed need no further adjustment during their working life. A range of stationary field magnetic units made by the firm can be utilised as clutch couplings, clutch brakes and duplex clutches. They are available in five sizes capable of transmitting torques from 4·2 to 420 oz in at speeds of up to 20,000 r.p.m.

A new series of "Kopp" variable speed gears of from $^1/_{33}$ to 15 h.p. with a stepless speed variation of 9 to 1 and designed to transmit constant horsepower throughout the output speed range is to be exhibited by Allspeeds, Ltd., Clayton-le-Moors, Accrington, Lancs. On this firm's stand there will also be a prototype speed corrector unit which has been designed automatically to adjust a varying speed so as to obtain a constant linear or rotary speed. This unit, illustrated in Fig. 10, operates over the full range of standard Kopp variable speed gears. With it the speed selected to suit the material or process is set on a dial control and maintained to within 1 to 5 per cent, depending on requirements. Provision can be made for an over-riding switch to give manual control and inching stations for presetting purposes so that speeds for new materials or processes may be obtained. The speed corrector unit is totally enclosed in a cabinet for panel or wall mounting.

Fuel Distribution Installation

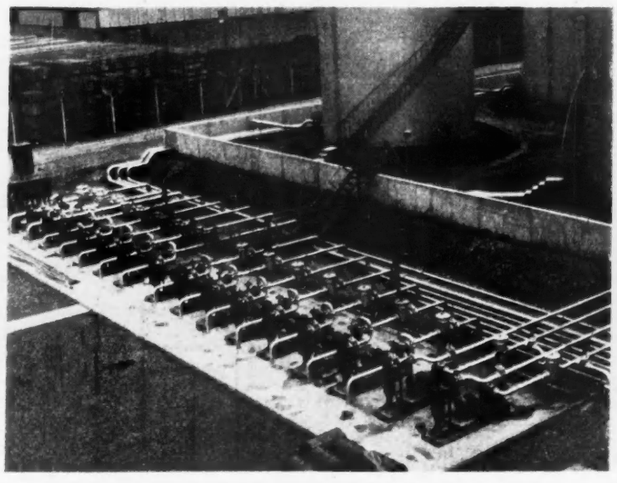
AT Royston, Hertfordshire, there was commissioned recently a new fuel distribution depot for Shell-Mex and B.P., Ltd. This installation has been designed to anticipate the pattern of demand for the company's products for the next five years and occupies a six acre site, on which the natural lie of the land has been developed to achieve the maximum economy in manpower, handling and control. To attain this, the layout has been carefully planned and the ground has been graded so that the rail tank cars enter at a higher level than the storage tank bases, which are, in turn, at a level higher than the pumps supplying the road vehicles, while a master control panel is located in the office block to provide automatic indication of movement.

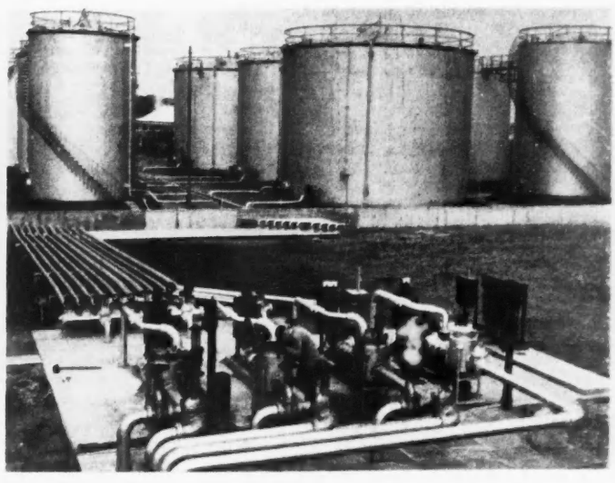
Overall movement of fuels will amount to about 130,000 tons per year and the various grades, consisting of motor spirit, diesel fuels, light fuel oils, are stored in ten tanks ranging in size from 100 to 500 tons and having a total capacity of 3500 tons or 1,000,000 gallons. Fuel is delivered in rail cars and the gantry at the railway siding is capable of accommodating a complete train of twenty-six rail cars. Both overhead and low-level suction lines are provided and for off-loading there are four Stothert and Pitt 50 tons per hour pumps, two for spirit, one for gas oil and Derv, and one for light fuel oil. Individual lines deliver fuel to each tank and blend valves, which are locally operated, subject to the over-riding control of the master panel, prevent fuel contamination. Provision is made, outside the bund containing the tanks, for foam injection, so that foam can be pumped to any tank in case of fire. Our illustration shows the pumps and the individual pipelines to the tanks.

All the tanks have fixed conical roofs having a centrally-mounted fire spray device, by means of which water pumped by the fire brigade from the mains or the 30,000 gallons static water tank will flow over the roof and down the tank sides. Also fitted to the roof is a pressure vacuum valve set to operate at 8in water gauge when the tank is being filled and 2½in when the tank is being emptied. An Evershed and Vignoles level indicator is installed and the readings are recorded on the master panel which also records the temperature of the tank contents as given by an indicator consisting of a resistance wire formed into a helical coil and attached to a float so that the temperature measured is an average reading. Each tank is earthed to give both static and lightning protection.

At the outlet from each tank is an electro-pneumatic 6in cast steel plug valve, manufactured by Audley Engineering Company, Ltd., which admits fuel to the suction lines leading to the pump apron. Here is a battery of pumps, illustrated herewith, consisting of twelve 50 tons per hour Hayward-Tyler centrifugal units, two 60 tons per hour Stothert and Pitt pumps for handling light fuel oil and two 20 tons per hour pumps of the same make for general duties. Off-loading headers are provided so that supplies may be delivered by road should the rail services prove uneconomic or be temporarily not available. From the pumps underground lines lead to the vehicle loading gantries which have eight loading points and can load thirty-two tankers in one hour. The pumps are push-button operated from the gantry and the fuel passes through an isolating valve, de-aerator, strainer, positive displacement rotary meter and a set stop valve which closes at a preset quantity and has a two-stage close, reducing to half-speed at a point 30 gallons short of completion. Delivery to the road tanker is via an Emco loading arm which incorporates, in its geometry, torque springs designed to give constant pull. At each arm is a swivelling counter head with ticket-printing attachment. The quantity required is set on the meter and the ticket is stamped only when the preset quantity has been delivered. As already mentioned, all the operations are under the control of the master panel located in the office of the installation manager. The panel, which is arranged in the form of a mimic flow diagram, provides automatic indication of the quantity and temperature of all the stocks in the tanks and embodies push-buttons to control the opening and closing of the inlet and outlet master valves. Light signals indicate which pumps are working, and loud speakers serve all key operating points.

Twelve grades of lubricating oil are stored in two six-compartment horizontal tanks which are filled by two 20-ton Plenty variable displacement





(Left) Railcar off-loading pumps and individual pipelines to tanks, together with foam injection connections. (Right) Battery of pumps supplying the road tanker loading gantries

pumps. The tanks load out by gravity. For servicing the road tankers there is a building having four bays. In No. 1 bay, where the vehicles are washed, there are three levels of lighting; next there is a greasing bay and in the third bay, which is flameproof, inspection and repairs are carried out, while the fourth bay forms a general store and workshop. For heating the administration block there is a 500,000 B.Th.U. oil-fired Potterton boiler fitted with Nu-way burners, and for circulating the hot water which passes through thermostatic mixing valves, there are two Mo-Pumps, one being a stand-by. Electrical equipment was manufactured by Ottermill Switchgear, Ltd. Drainage from the installation, which is built on a chalk base, passes through a weir pattern interceptor, and runs to six soakaways.

Industrial Research Development 1960*

RECENTLY a committee of the Department of Scientific and Industrial Research has reported some facts about the expenditure of industry on research and development. About £300 million was spent by British industry in 1958 as compared with about £190 million in 1955. Ninety-five per cent of the £300 million was spent in industry's own establishments, and about 5 per cent on payment to outside bodies, such as co-operative research associations, universities and other public and private research institutions. The main expenditure on research and development for the year under review was in aircraft (£100 million), electrical engineering (£64,000,000), and chemicals (£43,000,000).

These estimates of expenditure are based on the estimates of the distribution of qualified scientists and engineers engaged on research and development provided by a survey carried out in January, 1959, by the Ministry of Labour and National Service for the Advisory Council on Scientific Policy.† D.S.I.R. carried out a special inquiry designed to discover how the cost of employing a qualified worker‡ on research and development had changed since 1955. The results of this inquiry, described in the report, show that this cost varies greatly from one industry to another, and is related to the amount of development expenditure and the use made of supporting (not "fully qualified") staff. The average cost of a qualified worker for all manufacturing industry was nearly £11,000. In the case of the aircraft industry the figure was nearly £31,000 and the average for manufacturing industry other than aircraft was just under £8000. In 1955 the cost of a qualified worker was £5600, and the new figures represent an increase of 43 per cent, of which 14 or 15 per cent can be attributed to rising prices and incomes.

The amounts which different industries spend on research are given in Table I and in Table II they are compared with the estimates of net output in the Board of Trade's 1958 Census of Production. Research and development expenditure is analysed in Table III, and estimates given in Table IV are of payments for research by outside bodies.

The D.S.I.R. inquiry was based on a questionnaire sent out in April, 1959, to 502 companies known to be engaged on scientific or engineering activity. In reply 292 usable returns were received, giving a response rate of 58 per cent. Data on the iron and steel industry were supplied by the Iron and Steel Board. These returns together accounted for over half the fully qualified scientists and engineers estimated to be employed on research and development in all manufacturing industry other than the aircraft industry.

TABLE I—*Research and Development Expenditure Compared with Net Output**

	Net output*	Research and development expenditure	
	£ million	£ million	Per cent of net output
All manufacturing industries	7772·0	296·7	3·8
All manufacturing industries except aircraft	7492·1	196·7	2·6
Ceramics, glass, cement, &c.	294·9	3·2	1·1
Chemicals and allied trades	734·9	43·0	5·9
Metal manufacture	703·6	8·1	1·15
of which :			
Iron and steel	561·1	5·1	0·9
Non-ferrous metals	142·4	3·0	2·1
Non-electrical engineering and shipbuilding	2251·6	29·4	1·8§
Electrical engineering and electrical goods		64·5	9·8§
of which :			
Electronics	206·2	24·6	11·9
Aircraft	279·9	100·0	35·7
Motor and other vehicles and accessories	519·6	17·1	3·3
Precision instruments, &c.	108·6	11·6	10·7
Textiles, leather, leather goods and clothing	935·2	8·6	0·9
Food, drink and tobacco	940·0	5·0	0·6
Manufactures of wood and paper, and printing	777·8	2·0	0·25
Other manufacturing	225·9	4·1	1·8

Notes : * Net output represents the value added to materials by the process of production, including the gross margin of any merchanted or factored goods sold. The figures in this table are not comparable with those in Table VI in "Estimates of Resources Devoted to Scientific and Engineering Research and Development in British Manufacturing Industry, 1955," which related only to establishments with 100 or more employees.

§ Estimate.

‖ Research and development expenditure for man-made fibres amounted to 14·0 per cent of the net output of these fibres, ignoring spinning and weaving.

* Industrial Research and Development Expenditure, 1958. H.M. Stationery Office. Price 1s. 3d.

† *Scientific and Engineering Manpower in Great Britain*, 1959. Cmnd. 902.

‡ Qualified workers are graduates in pure science or engineering or persons holding equivalent professional qualifications as set out in Appendix to the Report.

TABLE II—*Estimated Expenditure on Research and Development, 1958 : Distribution by Main Industries*

	Total		Expenditure in industries own establishments		Payments outside bodies	
	£ million	Per cent	£ million	Per cent	£ million	Per cent
All manufacturing industries	296·7	100·0	283·0	100·0	13·7	100·0
All manufacturing industries except aircraft	196·7	66·3	183·1	64·7	13·6	99·5
Ceramics, glass, cement, &c.	3·2	1·1	3·0	1·1	0·2	1·5
Chemicals and allied trades*	43·0	14·5	42·4	15·0	0·6	4·4
of which :						
Mineral oil refining	6·8	2·3	6·7	2·4	0·1	1·1
Metal manufacture	8·1	2·7	6·8	2·4	1·3	9·5
of which :						
Iron and steel	5·1	1·7	3·9	1·4	1·2	8·8
Non-ferrous metals	3·0	1·0	2·8	1·0	0·15	1·1
Non-electrical engineering and shipbuilding	29·4	9·9	28·0	9·9	1·4	10·2
Electrical engineering and electrical goods	64·5	21·7	57·4	20·3	7·1	52·0
of which :						
Electronics	24·6	8·3	23·7	8·4	0·9	6·6
Aircraft	100·0	33·7	99·9	35·3	0·1	0·7
Motor and other vehicles and accessories	17·1	5·8	15·9	5·6	1·2	8·8
Precision instruments, &c.	11·6	3·9	11·5	4·1	0·1	0·7
Textiles, leather, leather goods and clothing	8·6	2·9	7·6	2·7	1·0	7·3
of which :						
Cotton	0·5	0·2	0·2	0·1	0·25	1·8
Man-made fibres	6·6	2·2	6·3	2·2	0·35	2·6
Food, drink and tobacco*	5·0	1·7	4·7	1·7	0·3	2·2
Manufactures of wood and paper, and printing	2·0	0·7	1·8	0·6	0·2	1·5
Other manufacturing	4·1	1·4	4·0	1·4	0·1	0·7

Notes : * Some research on food products is unavoidably included in "Chemicals and allied trades." The error is probably of the order of £500,000 which if allocated to "Food, drink and tobacco," would increase the total for that industry by 10 per cent.

TABLE III—*Analysis of Expenditure on Research and Development*

	Total £'000	Current expenditure					Capital expenditure £'000
		Salaries and wages	Materials and equipment	Administration	Repairs and depreciation	All other items	
		Per cent of total					
All manufacturing industries	253,765	44	22	10	12	12	29,242
All manufacturing industries except aircraft	157,045	50	18	8	12	11	26,044
Ceramics, glass, cement, &c.	2,447	32	17	6	39	6	546
Chemicals and allied trades*	35,402	52	14	9	14	10	6,979
Metal manufacture	5,711	49	16	8	11	16	1,039
Non-electrical engineering and shipbuilding	24,228	52	14	6	16	13	3,791
Electrical engineering and electrical goods	48,488	47	22	11	7	13	8,876
Aircraft	96,720	32	29	†	†	†	3,198
Motor and other vehicles and accessories	14,432	54	22	5	6	13	1,509
Precision instruments, &c.	11,209	54	27	4	7	8	336
Textiles, leather, leather goods and clothing	6,424	49	18	4	17	12	1,190
Food, drink and tobacco	3,459	56	10	8	16	10	1,223
Manufactures of wood and paper, and printing	1,481	45	7	28	13	7	265
Other manufacturing	3,764	55	17	6	14	8	290

Notes : See Note * to Table II.
† Insufficient data to support estimate.

TABLE IV—*Estimated Payments by Manufacturing Industries to Outside Bodies for Research in 1958*

	Total £'000	To Government departments and research laboratories	To co-operative research associations	To universities and technical colleges*	To other research institutions
		Per cent of total			
All manufacturing industries	13,664	2	29	4	65
All manufacturing industries except aircraft	13,582	2	29	4	65
Ceramics, glass, cement, &c.	227	3	86	2	9
Chemicals and allied trades	666	6	37	29	27
Metal manufacture	1,336	—	72	4	24
Non-electrical engineering and shipbuilding	1,412	16	58	6	21
Electrical engineering and electrical goods	7,101	—	3	1	96
Aircraft	82	—	23	18	59
Motor and other vehicles and accessories	1,158	—	8	—	91
Precision instruments, &c.	57	3	72	4	21
Textiles, leather, leather goods and clothing	995	1	85	4	10
Food, drink and tobacco	329	—	43	2	55
Manufactures of wood and paper, and printing	217	1	98	—	1
Other manufacturing	84	—	72	7	21

Notes : * This column does not include industrial contributions to research in universities and colleges in the form of fellowships or gifts of money or instruments to scientific departments for general research purposes.

SHORTER REPORTS

Steel Works Expansion Projects

UNDER a new development scheme costing a total of £32,500,000 Appleby-Frodingham Steel Company plans to increase its productive capacity for iron and steel and to install a new rod/bar mill, and Samuel Fox and Co., Ltd., is to add 100,000 tons a year to its steelmaking capacity. Both works are branches of The United Steel Companies, Ltd. These projects, which are scheduled for completion by the autumn of 1964, represent the largest development scheme undertaken by the company. When completed, together with other schemes already in hand, the ingot capacity of The United Steel Companies, Ltd., will be raised from its present level of about 3,000,000 tons to about 4,000,000 tons a year. At present, Appleby-Frodingham has a planned annual productive capacity of slightly exceeding 1,000,000 tons of plates and sections. By the end of 1964, however, with the addition of the output from the rod/bar mill, this figure will approach 1,400,000 tons of finished products a year. The decision to install a rod/bar mill with an additional capacity of 300,000 tons annually has been taken in order to diversify the company's output of finished products and to extract the full potential from the existing primary iron and steel making plant at Appleby-Frodingham's Scunthorpe works.

The introduction of additional plant to produce finished products to the extent of a minimum of 300,000 tons a year will call for increases in output as far back in the production sequence as the initial raw materials. Thus, United Steel's ore mining branch plans to increase the level of its iron stone extraction from 6,190,000 tons to 7,700,000 tons a year. All this additional ironstone will be extracted from the company's ore-fields in North and South Lincolnshire and Rutland. Meanwhile, it will be necessary to produce additional metallurgical coke for the Scunthorpe blast-furnaces, and United Coke and Chemicals Company, Ltd., is to provide an additional 323,000 tons a year by doubling the size of its Brookhouse coke oven plant and by adding 50 per cent to the capacity of its Orgreave plant. This expansion, integrated into the scheme, will have additional advantages in the Sheffield area in that it will provide additional supplies of coke oven gas through the existing pipelines to Steel, Peech and Tozer at Rotherham and Samuel Fox and Co. at Stocksbridge.

It may be recalled that Appleby-Frodingham Steel Company pioneered in this country the use of 100 per cent sinter burdens for blast-furnace operation. To produce the necessary additional tonnages of iron, increased tonnages of sinter of improved quality are to be made available to the company's four blast-furnaces by extensions to the present ore preparation plant. Large-scale trials, utilising sinter of improved size and physical condition, have already yielded significant increases in iron production. The proposed extensions, together with the addition of certain blast-furnace auxiliaries, including additional stove capacity, gas cleaning plant and boiler plant, will permit the pig iron output to be raised from its present level of 1,560,000 tons to 1,950,000 tons a year by the end of 1964.

Recently, Appleby-Frodingham announced the development of the "Ajax" oxygen process for the making of steel. This process was developed to utilise a conventional basic open-hearth tilting furnace for oxygen steelmaking. The steelmaking capacity at present available in the company's melting shops consists of ten basic open-hearth tilting furnaces and three mixers. In the main, the open-hearth furnaces are each of 300 tons capacity. Two of the open-hearth furnaces have already been converted to the "Ajax" oxygen process and a third conversion is now taking place. Under the proposed development scheme, five more open-hearth furnaces will be converted to the "Ajax" process while one open-hearth furnace will be converted, by rebuilding, to a hot metal mixer. When completed, these plans for additional ore mining, coke production, ironmaking and steelmaking, will yield an extra 400,000 tons of ingots a year, of which 350,000 tons will be required for the operation of the new rod/bar mill. The remaining 50,000 tons are expected to be absorbed by the expanding production of existing rolling mills. Surplus capacity for the rolling of blooms already exists in Appleby-Frodingham's cogging mill, which serves the section mills, and it is proposed to make this surplus capacity up to the equivalent of 350,000 ingot tons per annum by the installation of a four-strand continuous casting plant for the production of the remainder of the necessary blooms. The continuous casting plant is to be designed and manufactured by Distington Engineering Company, Ltd. It will be equipped to cast four strands of 9in square blooms, and will operate from 100-ton ladles of steel, with a weekly production capacity of 5000 tons. It is scheduled to begin operations in December, 1961. Liquid steel will be poured from the ladle into a common tundish, with four stopper-controlled nozzles feeding direct into the copper moulds. After leaving the spray cooling chamber, the solidified blooms, withdrawn through pairs of withdrawal rolls, will be cut off vertically into 30ft lengths. These will be discharged at ground level by a discharge conveyor mechanism. The blooms will then be transferred to a new 32in reversing mill for rolling into billets to feed the new rod/bar mill.

At the works of Samuel Fox and Co., Ltd., re-development of existing steel melting and rolling capacity will permit output to be increased from the present level of 400,000 tons to 500,000 tons a year.

Corrosion in Cast Iron

RECENT studies by Shell Research, Ltd., and the Fulmer Research Institute have thrown a new light on the problem of corrosion in cast iron, and are described in a paper "The Influence of the Silicon in Cast Iron on Corrosive Wear." This paper shows that the corrosion of cast iron cylinder liners and piston rings in diesel engines, caused by acids in combustion gases, occurs at a maximum rate when the silicon content is about 2 per cent and that a reduction of the silicon content to 1 per cent produces a marked improvement in corrosion resistance. Similar results were obtained from experiments with boiler gases.

A cast iron containing between 1 and 3 per cent silicon is considered satisfactory for resisting abrasive wear. A much higher silicon content, on the other hand, is known to provide good resistance to corrosion; and an iron containing 14 per cent silicon is the standard material for use with sulphuric acid. It had, therefore, been assumed that for cast iron with a silicon content in the 1 to 3 per cent range, the higher silicon content would give the better resistance not only to abrasion, but also to corrosion.

That this might not be so was suspected when cylinder liners, which had suffered excessive wear in marine diesel engines, were examined at the Thornton Research Centre of Shell Research, Ltd., and where tests suggested that silicon might have an adverse effect on the corrosion resistance of cast iron. The results indicated that the increase in corrosion when the silicon content was raised from 0·8 per cent to 1·8 per cent was nearly tenfold. These first tests were limited in their scope. The highest silicon content used was about 1·8 per cent and the samples differed not only in silicon content but in other respects, such as constituents and microstructure. However, the results were felt to justify taking the matter further, by carrying out further tests under more carefully defined experimental conditions.

The Fulmer Research Institute was asked to cast and prepare suitable specimens differing as far as possible only in silicon content, and to test them ten cast irons of similar structure, but ranging in silicon content from 0·59 per cent to 2·96 per cent, were produced, and tests confirmed the earlier results at Thornton, and indicated that resistance to corrosion was lowest where the silicon content was just above 2 per cent.

Further tests were carried out at Thornton to examine the effect of the silicon content under operating conditions. Piston rings were machined from castings containing 1 per cent and 2 per cent silicon respectively, and tested in a diesel engine, and the results confirmed that the cast iron with the lower silicon content had greater resistance to corrosive wear than that with the higher content. This was also found to be so even when a lubricating oil with additives designed to combat corrosion was used.

It was realised that the results obtained at Fulmer were significant not only for problems connected with diesel engines, and specimens of these cast irons were tested in boiler combustion gases at Thornton. The effect of silicon in these boiler tests was significant enough to emphasise the importance of a low silicon content. Here the greatest corrosion occurred when the silicon content was about 1½ per cent, rather than just over 2 per cent as in the previous tests.

Most of the work reported upon was done with cast iron chosen for its suitability in engines and machinery, but there is no direct evidence yet that the results will hold for other types. However, it has been shown that the higher silicon content often chosen to facilitate the production of sound castings for certain machinery can result in the worst resistance to corrosion. For the best resistance the silicon content must be kept low; certainly not higher than 1 per cent.

Institution of Civil Engineers

SOME 600 members and guests attended the annual dinner of the Institution of Civil Engineers in London on Thursday, April 21. In proposing the toast of the Institution, Lord John Hope, the Minister of Works, said that, like art, civil engineering knew no frontiers and much national prestige had resulted from the works carried out overseas by British civil engineers. New materials and techniques were being introduced in ever increasing numbers and were leading to a greater degree of specialisation in the profession in their application to meet design problems.

The importance of the work of the civil engineering profession to the national economy was later stressed by Sir Herbert J. Manzoni, the president of the Institution, who pointed out that in 1959 the industry was responsible for work to the value of £500 million in the United Kingdom. Work carried out abroad by contractors during the year totalled £100 million, or equivalent to one-thirtieth of the income from all British overseas trading. The sphere of influence of the civil engineer, said Sir Herbert, was very great, and much of the rise in the standard of health could be attributed to the industry. As a result of their increasing influence on the life of the country, civil engineers would have to concern themselves more with sociological and political spheres. This might lead to a dangerous degree of materialism, to combat which the humanities must be introduced to a greater extent in the training of engineers.

SHORTER REPORTS *(Continued)*

Colour Television System

DETAILS of the work done by the Compagnie Française de Télévision on the Henri de France colour television system were given in a paper by Messrs. R. Chaste and P. Cassagne, presented to the Electronics and Communications Section of the Institution of Electrical Engineers on April 27. This system takes advantage of the fact that when the bandwidth of chrominance signals is reduced, horizontal definition is lowered to an extent which is not perceptible to the eye, while vertical definition remains almost unchanged. It is possible, in fact, to supply the chrominance information in alternate lines in the vertical direction. The transmission consists, therefore, of a normal luminance signal and two complementary chrominance signals transmitted over a narrow band in alternate lines. Chrominance information not transmitted differs very little from that of the previous line, for which it was transmitted. At the receiver the information is considered as being identical because the eye cannot appreciate the difference. By means of a delay, three signals are provided for every line, although only two have been transmitted. They consist of the luminance, the chrominance information transmitted during that line, and the chrominance information transmitted during the preceding line. This last signal is made available by the inclusion of a delay line, which repeats the signal after the delay of a line period.

At any instant the chrominance signal transmitted follows two paths, one taking it directly to the decoding matrix before the cathode-ray tube, while the other makes it available for the subsequent line via the delay line. The arrangement described is compatible, since the black-and-white signal can be extracted from the composite signal by a simple filter. Conversely, since the principle of constant luminance is observed, as in the N.T.S.C. system, a colour receiver reproduces a black-and-white picture faithfully.

The latest designs of delay lines used in this system are multiple-reflection quartz lines. The transducers are ferro-electric cells of barium titanate which use the propagation of longitudinal sinusoidal waves in a solid medium of fused silicon. Special attention has been given to reducing the price and size of these components in the interests of producing simple and inexpensive receivers, and the delay lines described in the paper measure 1in in height and 3in in diameter.

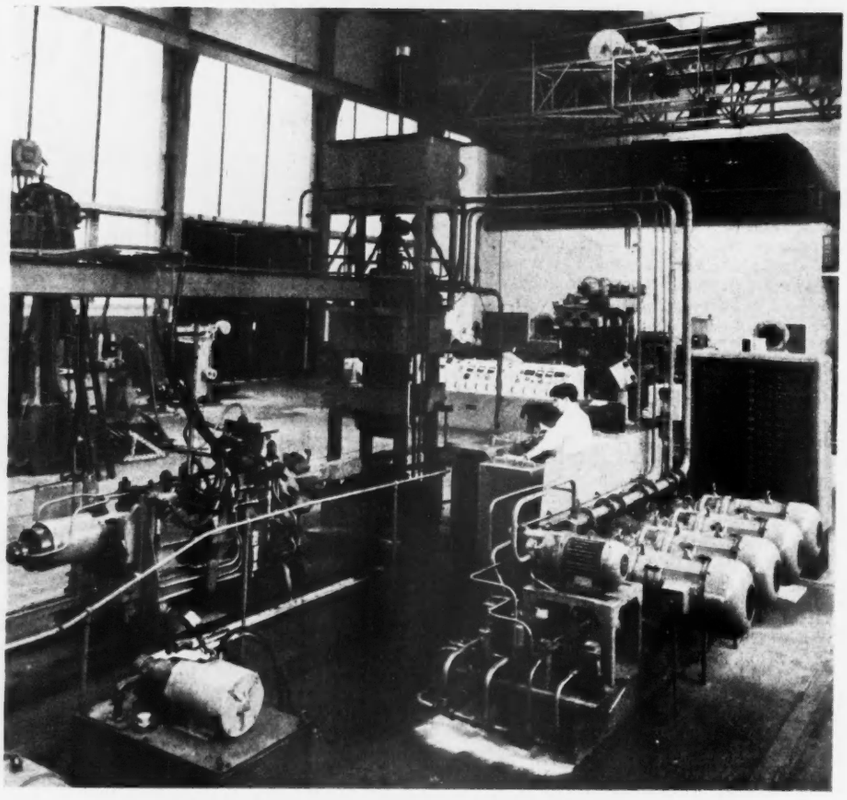
Automatic Forging

ABOUT five years ago, the British Iron and Steel Research Association initiated a programme of research into the fuller mechanisation of forging. The shortage of skilled forgemen and difficulty in recruiting them emphasised the need for this research. The programme was drawn up in three phases, namely, improvements to the operation of the forging press, the development of a suitable manipulator, and the synchronisation of the action of the press with that of the manipulator. There was also envisaged automation of the forging process by the introduction of programme control.

Last week we visited the B.I.S.R.A. laboratories at Sheffield, to see the progress on this research. During that visit, Dr. J. G. Wistreich, who has charge of the work, said that the original aims had changed and that the project was now generally referred to as "forge automation." The forge of the future, he added, might well be designed as follows: (i) pressing and manipulating function integrated in one machine; (ii) a dual-action press to work the piece faster and more homogeneously, and (iii) a dual-grip manipulator to hold the piece more firmly, with supporting rollers to take the weight.

The work so far accomplished on the project includes raising the efficiency of the forging press, using the B.I.S.R.A. 200-ton experimental press, illustrated herewith. By improvements in the hydraulic system, the rate has been increased to sixty cogging strokes a minute and, concurrently, a system of remote position control has been developed which enables the amount of squeeze to be predetermined to within $\pm\frac{1}{16}$in. The control includes provision for repetitive stroking of the press cross-head between fixed limits. When this was achieved, attention was turned to the manipulator, also shown in the illustration. The aim was for a design incorporating longitudinal feed, accurate radial movement through 90, 45, $22\frac{1}{2}$ and $7\frac{1}{2}$ deg., and adjustable height. The manipulator had to be fast and accurate enough to match the performance of the improved press. The machine was primarily conceived as a piece of apparatus for working at the press and was therefore made rail-bound. Provision was made in the electrical control system for synchronising the movement of the press and manipulator, so that as the press cross-head moved up on its return stroke, the workpiece was immediately moved to the next working position by the manipulator.

The next step was the "programme control" of both press and manipulator. Investigation of metal shaping was therefore carried out to establish the precise sequence of squeezes and manipulator movements required for a particular forging operation. Previously these steps had been arrived at by empirical methods, and B.I.S.R.A.'s investigations constituted an attempt to rationalise procedure, so that a predetermined programme could be formulated. As yet, theoretical schedules have only been worked out for square bars, but further work continues on other shapes. An experimental control device has been devised for applying these programmes to the combined press and manipulator, successfully demonstrating that the principles of programme control are now a practical possibility. In recent trials of the programme control, a test forging was completed to a better-than-average standard of accuracy in four-and-a-half minutes; this was about twice as fast as the best skilled forging crew would be capable of doing. Trials of the programme control unit are being continued with the object of developing improved programming techniques.



B.I.S.R.A. 200-ton experimental forging press and manipulator

Combustion Additives for Boilers

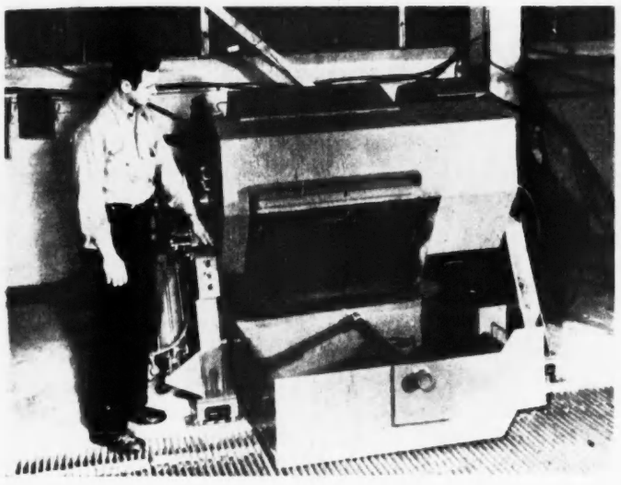
WE have been informed that the Amber Chemical Company, Ltd., has introduced its Amber SSR117 which is a powder additive in a soot stick form for the treatment of industrial and marine boilers, using either liquid or solid fuels. It is supplied in $\frac{1}{2}$ lb tubular injector cartons and it is claimed that it reduces soot and carbon deposits and slag formation, while sulphur corrosion is lessened by a reduction in the formation of SO_3. These benefits improve the operational efficiency of the boiler by reducing the frequency of tube cleaning and increase the heat transfer. The nuisance caused by heavy stack emission is partially alleviated by the use of this combustion additive which also protects furnace refractories and reduces exit gas temperature.

Designed to overcome sludge and other problems associated with the burning of heavy fuel oil, the company produces Amber SSR511, a marine fuel additive, which is a non-viscous chemical compound. It dissolves sludge in tanks and prevents further sludge formation and keeps fuel oil heaters clean and by improved atomisation ensures better combustion. The additive reduces carbon deposits on burner tips, the formation of soot and scale, corrosive sulphur deposits and prevents instability of oils.

[Reply Card No. E7463]

Vibratory Finishing Machines

AN arrangement for the manufacture of vibratory finishing machines in this country has been concluded between the Hepburn Conveyor Company, Ltd., of Wakefield and the Pangborn Corporation of the United States. This vibratory equipment for finishing components, which is designed to replace conventional barrel finishing, is stated to be more than ten times faster and to require less media and compounds for given amounts of work. A typical machine is illustrated herewith; it incorporates means of varying the amplitude and frequency to cover a wide range of different components. The machine can be used for either severe cut-down (it being claimed that up to 0·025in of stock can be removed from stainless steel components in thirty minutes), or for finishing delicate components (in which it is stated laminations 0·006in thick and 4in diameter can be deburred and finished without distortion). Further claims made for the vibratory system is that interiors and shielded surfaces which are unsuitable for conventional barrel cleaning can be readily processed.



Vibratory finishing machine with means of varying amplitude and frequency to suit different classes of component

A plant has been installed at he works of the Hepburn Conveyor Company, Ltd., for testing customers' samples and to demonstrate the capacity of the equipment for various classes of components in cleaning, deburring, descaling, radiusing, fine finishing, colouring and burnishing. Machines of 1½ to 18 cubic feet capacity are being made and supplied complete with the requisite compounds and media by the British firm.

[Reply Card No. E7471]

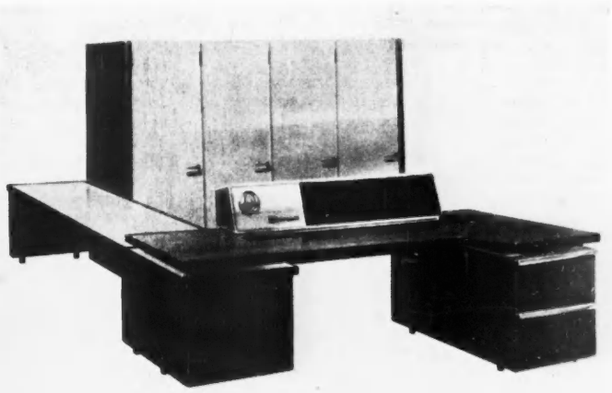
Air Traffic Control Computer

THE accompanying illustration shows the "Apollo" computer developed by Ferranti, Ltd., Hollinwood, Lancs, for the air traffic control experiment initiated by the Ministry of Aviation. A paper on the computer and its application was presented to the I.E.E. symposium on Data Handling and Display Systems for Air Traffic Control (see our April 15 issue), and Ferranti, Ltd., now announces that the computer, which will be the first to be used for air traffic control experiments in this country, will go into operation at the Scottish air traffic control centre, Redbrae, Prestwick, early in the spring of next year.

The "Apollo" is a high-speed, transistorised, parallel computer working in real time. It consists basically of three cabinets, each 6ft high, 22in wide and 19in deep. Positioned alongside the computer is a table accommodating a number of Creed 25 tape punches and in front of the computer is the control desk for mounting a Ferranti TR5 tape reader and a Creed 75 printer.

The left-hand cabinet contains racks of printed packages which carry out the arithmetic and control operations of the computer; next to that is the cabinet containing the programme and data store as well as the power supplies. The third cabinet contains input/output logic for control experiments. A fourth cabinet, on the extreme right, contains electronic equipment developed by the Ministry of Aviation, in conjunction with R.R.E., for cathode-ray tube displays. Each cabinet is equipped with cooling fans. Power consumption of the complete equipment is about 2kW.

Altogether, there are about 350 packages used in the machine, about 80 per cent of which are of six basic types. Most of the computer, however, is constructed from only two types of unit, a flip-flop temporary storage element and a single type of logical gate. It employs magnetic core stores of 4096 words capacity for programming and 4096 words for data, with cycle times of the order of 6 microseconds. Typical examples of instruction times are: simple orders 6 or 8 microseconds; shifts, multiplication, division, up to 60 microseconds. When completed, this computer will be one of the fastest in operation in Britain. The word length is twenty-four binary digits which will be used in three ways: (i) binary number with sign; (ii) four six-bit characters; (iii) instruction.



The "Apollo" computer which will begin experimental operation next spring at Prestwick air traffic control centre

For processing flight information, the computer will receive data from the local operators via four Creed 75 printers with keyboards, after sorting in conjunction with a controller so that only relevant information will be passed to the buffer store. At the same time, a record of what has been typed will appear on the printer associated with the keyboard, and if the operator is satisfied that everything is in order, he will then press a key on the keyboard, instructing the computer to transfer the information into the main file.

Depending on the message, certain stored programmes are brought into action and data are processed and checked for conflict. If the information concerns a flight plan it is stored until the departure time is received. This information is then processed and flight progress strips are printed out automatically on Creed 75 printers. This is done according to a time criterion, which enables the strips to be entered on a board in readiness for the entrance of an aircraft into the controlled area.

There are four Creed 75 printers with functional keyboards, one for use by each controller, enabling them to make requests to the computer, such as asking for flight strips before they are printed out, or any other relevant information. The Creed 75 printers have been developed by the manufacturer in conjunction with Ferranti, Ltd., to transmit and receive parallel code signals.

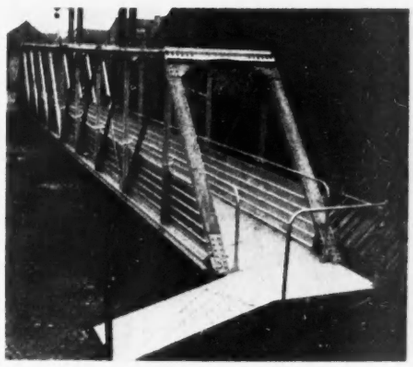
Two Creed 25 paper tape punches are employed for data output which is then analysed for functions of air traffic control. Provision is also made for information to be transmitted over normal serial teleprinter lines from a remote source directly to the computer memory via a converter unit. In consequence, new information can be inserted into the computer memory at will from other control centres. In the air traffic control system planned for the future, information such as this could emanate directly from other computers and in this way the task of processing flight information could be shared by air traffic control centres throughout the country.

Cathode-ray tube visual displays are employed as another means of showing numerical data stored inside the computer memory to the controller, and they may also be used to show plan position information. For real time operation, a time register containing a number representing G.M.T. is fed by pulses from a master clock, but for non-real time applications the register can be fed from an independent variable oscillator.

[Reply Card No. E7472]

Light Alloy Gangway

BELOW there is illustrated the shore end of a light alloy gangway recently built by Non-Corrosive Metal Products, Ltd., dismantled and shipped to Ghana for service with the Tema Port Authority. The gangway has an overall length, including ramps, of 86ft and a span between supports of 75ft, while the clear inside height to allow passage for natives carrying loads on their heads is 8ft, the overall height being 9ft. A clear width of 4ft has been provided between the handrails and the width over the construc-



Light alloy gangway including shore end ramps

tional members is 6ft. Of riveted and bolted construction, the gangway has been built of heat-treated extruded sections in aluminium alloy HE.30.W.P. and tread plate in alloy HP.10.W.P. The gangway has a self-weight of 1 ton 14 cwt, and when tested with a load of 100 lb per square foot, amounting to a total of 13 tons 10 cwt, the maximum deflection was 1·22in at the centre of the span.

[Reply Card No. E7473]

SHORTER REPORTS *(Continued)*

Flow Recorder for Cone-and-Plate Viscometer

AN automatic flow-curve recorder is now available for use with the Ferranti-Shirley cone-and-plate viscometer which is designed for the study of the flow behaviour of complex fluids. The cone-and-plate viscometer is made by Ferranti, Ltd., Hollinwood, Lancs, and the associated flow-curve recorder adaptor unit is supplied by Scientific Furnishings, Ltd., Poynton, Cheshire.

With this combination of instruments, illustrated here, non-Newtonian flow curves of shear stress against rate of shear can be plotted automatically, thereby eliminating the necessity for constructing graphs by time-consuming manual methods. The system also constitutes a convenient means of standardising test procedure to reduce errors caused by inconsistent experimental conditions. This improvement is particularly important for the measurement of time-dependent flow properties, e.g. with thixotropic substances where close control of both the magnitude and duration of shear is essential. The recorder is capable of plotting a complete shear stress/rate characteristic in about ten seconds for most non-Newtonian fluids.

With the existing cone-and-plate viscometer, the fluid to be examined is sheared in a narrow gap between a stationary flat plate and a slightly conical rotating disc, driven (at controlled speeds, ranging from 0·1 to 1000 r.p.m.) by a variable speed motor. The cone speed is directly proportional to the rate of shear. The amount of viscous drag on the cone is shown on an indicator unit and is directly proportional to the shearing stress. Thus, at any rate of shear or shearing stress, the apparent viscosity can be readily determined and flow curves plotted.

Cone-and-plate viscometer with automatic flow-curve recorder and associated amplifier and control unit

The new equipment comprises a flow-curve recorder adaptor unit, designed to fit beneath the existing viscometer indicator unit—so that all controls are readily accessible in one assembly—and a Houston Instruments HR-92 X-Y recorder. The latter instrument has been chosen for use with the equipment because of its small dimensions, compatible input and performance characteristics and moderate cost. However, most types of X-Y recorder can be used provided they have the correct input characteristics.

In operation, the control unit generates a voltage which increases linearly with time and is applied to the d.c. servomotor in the measuring unit via an amplifier, to accelerate the cone up to a pre-determined velocity. The tacho-generator, which is an integral part of the servo-mechanism controlling the cone velocity, supplies the speed signal to the Y-axis of the recorder, calibrated in revolutions per minute. The corresponding torque acting on the cone is measured by an accurate dynamometer consisting of a spring and potentiometer which supplies the torque signal to the X-axis, calibrated in dynes-centimetre. Multiplying by the appropriate cone constants gives the shear stress/shear rate characteristic in absolute units. On reaching the maximum speed the cone normally reduces speed automatically to zero, but a "hold" switch has been incorporated to maintain the preset speed constant for any desired time before speed reduction is initiated.

There are eight available rates of acceleration, the cone velocity being swept from zero to maximum speed (10, 100 or 1000 r.p.m.) in a time ranging from 10 to 600 seconds with a linearity of about 1 per cent. Intermediate maximum speeds can be selected by means of a ten-turn potentiometer. However, in applications where the duration of shear must be minimised, e.g. when accelerating to a specific cone velocity before starting the test proper, a rapid acceleration/speed reduction control with a sweep time of about one second is available: it is an overriding switch control and, as such, it may be used to speed the setting up and resetting operations. The sweep voltages are generated by a conventional Miller integrator.

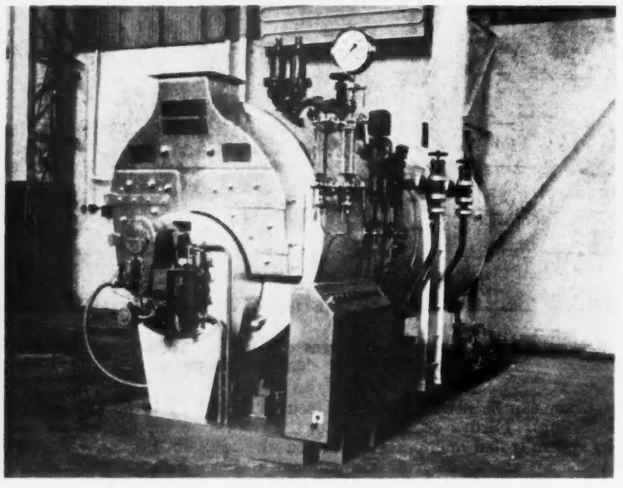
Viscosity or shear stress can be recorded against time at a constant pre-determined shear rate, by utilising the sweep voltage as a time base on the Y-axis of the recorder, with manual adjustment of the cone speed. The decay of stress with time can also be plotted in a similar manner.

[Reply Card No. E7481]

Boiler Research Building

To facilitate the development of its products, Cochran and Co., Annan, Ltd., has completed at its Newbic works, a new research and development building, which covers an area of 4000 square feet. The development shop can accommodate several full-size boilers and associated test equipment, while the construction of the roof permits chimneys to be taken out at various points without affecting the actual structure. Boilers installed in the shop at present, include: a 7ft diameter "Sinupac" unit rated at 9200 lb per hour from and at 212 deg. Fah. on oil firing, and 7500 lb per hour when fired with coal, of 11,500 B.Th.U. per pound; a 5ft 3in diameter boiler of the same mark and rated at 3750 lb per hour; and a Series II, 4ft 9in diameter vertical boiler having an evaporation of 1750 lb per hour. Supplementing the shop is a laboratory for the sampling and analysis of fuels and the analysis of feed water so that the correct recommendations for water treatment may be made. The laboratory will also deal with problems concerned with cold end corrosion, smut emission and deposits.

The company also announces the introduction of a new range of horizontal "packaged" boilers having a high performance, with either coal or oil fuel, for steam or high-pressure hot water. Given the name "Sinupac" the boilers are available with ratings from 3750 lb to 37,000 lb per hour when oil-fired, and from 7500 lb to 23,500 lb per hour when coal-fired, and are of welded construction. The oil-fired version, an example of which we illustrate, is fully automatic in operation, the pressure being maintained constant within narrow limits over the full operating range. Fuel and air supplies are limited to maintain good combustion over the turn-down ratio of the burner while should the boiler load fall below a predetermined figure the burner will switch on or off as required. The water level is maintained automatically, but should the water level become too low, cut-outs cause the burner to be shut down. Ignition is by a high energy spark, or spark and gas. For the coal-fired unit a coking stoker and induced draught fan are provided. For this range of boilers it is claimed that performance represents an efficiency of over 80 per cent on gross calorific value of the fuel, oil or coal, over an operating range from full load down to quarter load. Boilers can be built for operating at up to 250 lb per square inch.



Oil-fired version of range of "Sinupac" boilers

[Reply Card No. E7482]

Nickel Exhibition

THE Mond Nickel Company, Ltd., is holding an exhibition, at Moore's Hotel, Glasgow, from May 3 to 6, which is intended to emphasise the importance of nickel and platinum metals in modern industry. The exhibition is divided into sections as follow: properties at elevated, normal and sub-zero temperatures; corrosion-resisting properties; special physical properties, including catalysis, magnetism and controlled expansion; and special methods of fabrication, including welding, electroforming and powder metallurgy. Also included are nickel-aluminium bronze propellers and new improved castings in gun metal, while a particular item of interest will be discussions, led by members of the company's development staff, on such subjects as: "Nickel Alloy Steels," "Alloy and Special Cast Irons," "Industrial Applications of Platinum Metals," and "Nickel Plating."

Supervisory Control of Pumping Stations

PUMPS at the intake, high-lift and booster pumping stations on the River Dove Water Board's pipeline from a site near the confluence of the rivers Dove and Trent to the terminal reservoir near Leicester are under centralised supervisory control from the board's new pumping station and treatment works at Melbourne, Derbyshire. Control is exercised over a remote control and telemetering installation supplied by Standard Telephones and Cables, Ltd., Connaught House, Aldwych, London, W.C.2.

The remote control and indication system for the intake pumping station, 7½ miles from Melbourne, functions over a four-wire telephone line, rented from the G.P.O., connecting the station to the control room. The system uses a two-way, twelve-channel, frequency-shift-modulated telegraph system for the transmission of control signals from control room to pumping station and indication signals in the opposite direction. This equipment incorporates transistor circuits throughout. A view of the rack-mounted apparatus is reproduced. Provision is made for the control, initially, of two constant-speed pumps, one variable speed pump and a rotary screen, and, ultimately, for the duplication of all this plant. Speed adjustment, as well as starting and stopping of the variable-speed pump can be remotely controlled. Control functions are initiated from pushbuttons on the control desk illustrated, the operation of a push-button resulting in the transmission over the G.P.O. line of a predetermined combination of tones. Receipt of these signals at the intake station operates relays which in turn complete the selected control circuits for as long as the pushbutton is pressed. Response is virtually instantaneous. The control desk provides for control in future of the adjoining extraction pumping station which will come into use when the new Staunton Harold Reservoir is completed.

Indications fall into two categories : (*a*) telemetered readings of varying quantities, and (*b*) positional indications, relating to availability of supplies, running or stopped conditions of plant and alarms. Every telemetered reading is allocated a signalling channel and is transmitted continuously over the G.P.O. line as an interrupted tone, the rate of interruption being directly proportional to the measured quantity. Readings of pump speed, motor current and pumping rate, for which a fast response is required on the control room instruments, each occupy a complete signalling channel, whereas readings of delivery head, river and sump level and river flow, where slower response is acceptable, each occupy half a signalling channel.

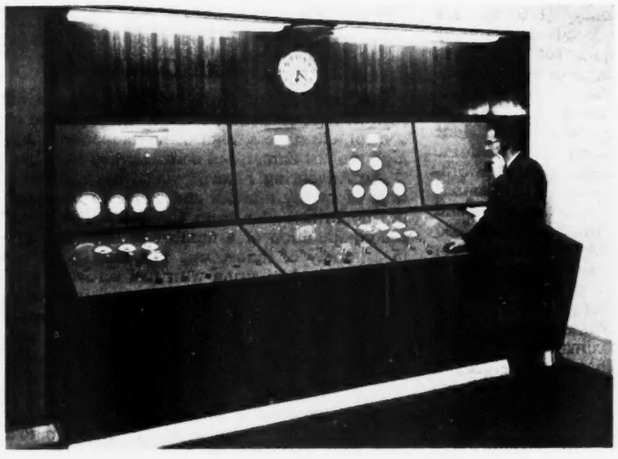
The positional indications are transmitted only when a change of position occurs, or when a check key is operated on the control desk. In either case, a scanner at the intake pumping station examines every indication and sends over a telegraph channel, reserved for this purpose, a code which includes all the required information. A decoder at the control room interprets the signal and illuminates the appropriate lamps on the control desk. When a signal is sent as the result of a change of conditions, an audible warning is given in addition to the visual indication.

Similar facilities are provided for the remote control initially of three, and ultimately of five, pumps at the high lift pumping station adjacent to the treatment works. As the distance between the pump-house and the control desk is short, direct-wire techniques are employed. To facilitate operation, however, the form of presentation on the control desk is the same as for the intake pumping station.

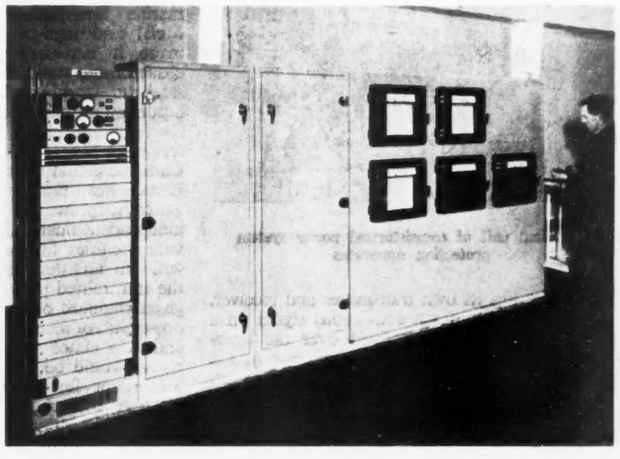
The remote operation of the booster pumping station at Belton, 5 miles from Melbourne, is effected over a two-wire circuit rented from the G.P.O. Common start/stop control is provided for the two pumps, together with continuous indications on the control desk of pumping rate. These limited facilities do not justify the use of multi-channel telegraphy and the system employed is based on the use of a mains-derived a.c. supply used as a carrier for superimposed control and telemetering signals.

At all locations the remote readings of water flow, level and pressure are derived from local instrumentation equipment provided by George Kent, Ltd.

[Reply Card No. E7491]



Control desk with remote control panels for intake, extraction and high-lift pumping stations



Voice-frequency telegraph rack, remote control and indication apparatus, and local instrument panel at intake pumping station

Switchgear Battery Unit With Controlled Charging

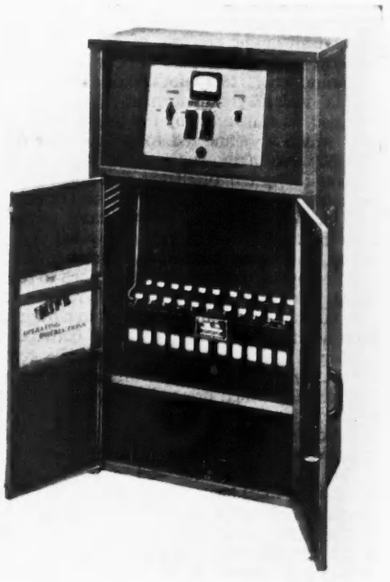
A SELF-CONTAINED switchgear unit, incorporating an automatic charge circuit, intended for use on unattended substations, has been developed by Nife Batteries, Ltd., Redditch, Worcester. It is designed to provide maintenance-free battery capacity capable of giving the short-rated discharges required for closing and tripping switchgear.

A new system of battery charging is embodied in this "Nife-O-Matic" switchgear unit to keep the battery fully charged by compensating for normal discharge loads as well as external leakage currents. In the charging circuit a condenser is connected in series with the primary winding of a specially designed transformer which operates with its core at saturation point to ensure that the voltage across the transformer primary is maintained at a constant value, even with a variation of ±6 per cent in the mains supply voltage. Thus, the voltage of the rectifier output circuit can be stabilised at a predetermined value such that the input current to a fully charged battery is only a few milliamperes. When the battery voltage is lowered by intermittent discharges, the output of the charger rises immediately and, as there is no ballast resistance in the circuit, the current is limited solely by the forward resistance of the rectifier which is generously rated. The charging current tapers back to a few milliamperes again as soon as the battery voltage has been restored, thus preventing excessive gassing and loss of water.

The "Nife-O-Matic" switchgear units are stated to be particularly suitable for the closing and tripping of switches associated with electric arc furnaces where the frequency of operations may be upwards of 250 a day.

A typical unit is illustrated here. The equipment is completely static and includes a twenty-five cell "Nife" nickel cadmium alkaline battery which is stated to need topping-up only once a year. The enclosure is of folded steel construction with enamel finish in dark Admiralty grey. A sloping control panel and printed aluminium fascia form the front of the upper compartment which contains the charge circuit equipment. Steel hinged doors give access to the battery and there are ventilation louvres in the sides of the battery compartment.

[Reply Card No. E7492]

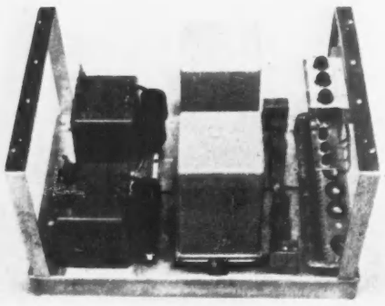


Switchgear battery unit with controlled charging

SHORTER REPORTS *(Continued)*

Voice-Frequency Intertripping System

DESIGNED as a power system protection link between substations, the SL.54 transistorised voice-frequency intertripping system introduced by The English Electric Company, Ltd., Marconi House, Strand, London, W.C.2, is stated to be the first in this category built completely round transistors and logic circuits. Each terminal unit of the system, one of which is



Terminal unit of transistorised power system protection apparatus

illustrated, has its own transmitter and receiver. In healthy conditions a continuous signal on a given frequency is transmitted over the interconnecting G.P.O. lines to the receiver at the other end of the line. When a fault occurs this frequency is shifted and the change, detected by the appropriate receiver, causes operation of a relay which in turn initiates whatever action is required. On a normal power line the time taken to relay a signal for tripping a circuit will not exceed 55 milliseconds, and under the worst conditions 85 milliseconds.

A typical application is where a step-down transformer is connected to the remote end of a 33kV line. Here, a fault on the low voltage side of the transformer will not necessarily be detected by the protective relay at the supply end of the feeder and under this condition problems arise in tripping the circuit breaker at the supply end. This is particularly true if the fault level on the l.v. side of the transformer is restricted by an earthing resistor. This difficulty is overcome by the use of intertripping equipment initiated from the l.v. side of the transformer.

The transmitter consists of an oscillator, an amplifier and a band-pass filter which feeds the transmitter signal to a pilot line or carrier channel via an isolating transformer. The oscillator frequency is controlled by the intertripping send relay which is connected to the fault detection circuits. Normally, with the send relay open (i.e. no fault) the oscillator will operate on a frequency f_1. During a fault condition, the send relay is closed and the oscillator frequency is reduced to f_2. The receiver is fed, via the common isolating transformer, from the same line used by the transmitter and is tuned to receive signals from the transmitter at the remote location. Incoming signals are applied to a frequency discriminator which distinguishes between the holding and trip frequencies from the remote location and passes the resulting information to logic circuits which determine whether the local switchgear is to be tripped or not. Two groups of logic circuits are provided. The alarm logic will give warning in the event of faulty operation of the SL.54 equipment and at the same time prevent the local switchgear from being tripped. The trip logic will cause the local switchgear to be tripped only when the trip frequency is detected by the receiver and then only if the alarm logic indicates that the SL.54 equipment is functioning correctly.

The conditions under which the alarm logic will give a warning are complete absence of received signal, received signal amplitude outside limits, or excessive noise on the signal. Alarm will also be given if the power supply for the equipment fails.

The equipment illustrated comprises a mounting panel accommodating two channel units (transmitter and receiver), two isolating transformers, alarm lamps, test jacks, fuses and connectors. The two channel units can be operated independently or in conjunction with each other for relaying fault information to other locations. A cover encloses the complete unit, which measures 20in by 12in by 12in.

[Reply Card No. E7501]

Marine Single-Sideband Transmitter

INCREASING radio telephony traffic in the marine intermediate-frequency (1·6 to 3·8 Mc/s) and high-frequency bands has already made it necessary to equip certain British coastal radio stations for single- or independent-sideband working, and similar conditions are occurring in many parts of the world. To meet the requirements of ships participating in these services, The Marconi International Marine Communication Company, Ltd., Chelmsford, Essex, has introduced a new transmitter, 2482AA, primarily for single-sideband and independent-sideband r/t working, but also with facilities for double-sideband r/t and for w/t. In addition to the saving in bandwidth, the transmitted power on single-sideband for a given standard of received signals need be only one-eighth of that required with double-sideband, and it is stated that approximately 8kW peak power would be required in a double-sideband transmitter for the results obtained from the 2482AA with a peak envelope power of 1kW on 1·8 to 12 Mc/s, and 900W on 16 and 22 Mc/s.

The transmitter, seen in the accompanying illustration, installed in the P. & O. liner "Himalaya" comprises a bench-mounted aluminium cabinet containing eight units fitted on runners for easy inspection and withdrawal. One of these, for frequency-shift keying, is optional. A separate power unit may be installed away from the transmitter or used as a base on which the transmitter cabinet may be mounted. Ten spot frequencies are provided in the 1·8 to 3·8 Mc/s band and in each of five

Single-sideband transmitter (left) for intermediate and high-frequency radio telephony in the P. & O. liner "Himalaya"

h.f. bands. In the 6 Mc/s band a maximum of four frequencies is available. Output power on all services may be reduced in three steps, each of approximately 5 dB. The transmitter may be operated either into the usual type of ship's single-ended aerial or an unbalanced co-axial feeder of 50-75 ohms impedance. An external matching unit can be used to match the feeder to the aerial.

Facilities are provided for connections to an associated receiver for receiver desensitising on simplex r/t and c.w., sidetone to receiver on c.w., r/t sidetone to local handset, receiver loudspeaker muting for duplex working, and duplex rejector unit control. Approximate dimensions of the transmitter are 4ft 2½in high, 2ft wide and 2ft 2in deep. The weight is approximately 300 lb.

[Reply Card No. E7502]

Firing With Oil Fuel

THE technical advantages claimed for fuel oil such as high efficiency, constant quality, ease of control, cleanliness, high flame temperature and high radiant flames, are demonstrated in a film, "The Advancing Flame," which has a running time of twenty minutes and has been produced by the British Petroleum Company, Ltd., with the co-operation of a number of firms engaged in a variety of industries. The film shows the high standard of firing with fuel oil which has been achieved in a wide range of industries, including steel making, non-ferrous metals production, brick manufacture, bakeries and laundries. In addition to present industrial applications, the film deals with future trends and indicates that research and development, a considerable share of which is carried out by the company, are endeavouring to attain higher efficiencies and to apply oil-firing techniques to new industrial developments. In particular, "The Advancing Flame" shows the investigation into drop size distribution, flame radiation, gas flow in boilers, high intensity combustion and two-stage combustion, all of which affect plant design and processes.

[Reply Card No. E7503]

Launches and Trial Trips

CRAIG-GOWAN, trawler; built by John Lewis and Sons, Ltd., for Bon-accord Mutual Ship's Stores, Ltd.; length overall 109ft, breadth 21ft 6in, depth moulded 11ft, gross tonnage 163; fishroom 4100 cubic feet, A.K. diesel, reversible belt-driven trawl winch, barrel capacity 500 fathoms of 2½in warp; two 15kW diesel-driven generators; Widdop, G.M.B.4 diesel engine, 440 b.h.p. at 300 r.p.m. Trial, February 4.

VISTAFJORD, cargo liner; built at Wallsend by Swan, Hunter and Wigham Richardson, Ltd., for Skibsaktieselskapet Malmtransport, Oslo; length between perpendiculars 470ft, breadth moulded 63ft 6in, depth moulded to upper deck 41ft 1in, cargo capacity 660,780 cubic feet bale; deadweight 13,880 tons on 30ft 6¾in draught; service speed 14¼ knots; four passengers; five holds, three 200kW diesel-driven generators; Kincaid - B. and W. two-cycle, single-ac opposedting, -piston oil engine, four cylinders 750mm diameter by 2000mm combined stroke, 5600 b.h.p. at 112 r.p.m. Trial, February 9.

ADVENTURER, heavy lift cargo ship; built by William Doxford and Sons (Shipbuilders), Ltd., for the Charente Steamship Company, Ltd.; length overall 490ft, breadth 65ft, depth 37ft 9in, 180-ton derrick to serve two hatches, service speed 15 knots; Doxford opposed-piston oil engine, six cylinders 670mm diameter by 2320mm combined stroke. Trial, February 11.

SUN XXII, tug; built by Philip and Son, Ltd., for W. H. J. Alexander, Ltd.; length between perpendiculars 100ft, breadth moulded 25ft 6in, depth moulded 12ft 8in; static pull 18·5 tons, free running speed 12·5 knots; two 62·5 kVA diesel-driven alternators, Mirrlees KLSSG.M.R.6 pressure-charged diesel engine, six cylinders, continuous rating 1400 b.h.p. at 375 r.p.m., drive through Modern Wheel Drive reverse reduction gearbox to deliver 1316 s.h.p. at 125 r.p.m. to the propeller. Trials, February.

INDUSTRIAL NEWS

Export Credits Guarantee Department

The Export Credits Guarantee Department has reported a satisfactory trading year during 1959–60. The volume of exports insured was larger, there was a bigger volume of contingent commitments outstanding at the end of the year and a corresponding increase in the cumulative reserve to cover those increased commitments. The Department says that in the year 1959–60, roughly 20 per cent more business was insured than in the preceding year (£694 million compared with £570 million). The percentage of total United Kingdom exports insured with the E.C.G.D. rose from 16 per cent in 1958–59 to 18·4 per cent last year.

At a press conference last week, the secretary of E.C.G.D., Mr. L. J. Menzies, referred to some improvements in the Department's cover which are to operate from May 1. At present, he said, the "whole turnover" (and selected markets) cover for engineering goods was limited to business done on up to three years' credit; from May 1, that three-year restriction was being removed. But, Mr. Menzies continued, that did not in any case involve any consequential lengthening of terms; for each case, the Department would continue to agree the appropriate terms of cover on the basis of the nature of the goods, the scale of the contract, and current practice in the trade. It did mean, however, that in future the only test as to whether business should be covered under a "whole turnover" policy or a specific policy would be whether the business lent itself to the "whole turnover" technique. The Department was confident, Mr. Menzies added, that this development would be a substantial benefit to those manufacturers of engineering goods which did not fall into the category of capital goods, yet which in certain cases nowadays had to be sold on credit longer than three years. By covering those transactions within their "whole turnover" policies, policy holders would enjoy premiums 25 per cent lower than those for the specific cover they had formerly required.

Oil Consumption in 1959

According to information provided by the Petroleum Information Bureau, oil consumption in the United Kingdom rose from 31,065,629 tons in 1958 to 36,514,044 tons in 1959, representing an increase of 17·5 per cent. Among the major products, fuel oil consumption totalled 13,811,874 tons and gas/diesel oil amounted to 3,123,477 tons, while Derv fuel increased by 11 per cent to 2,275,803 tons. Motor spirit consumption rose by 7·5 per cent to total 7,123,569 tons, but aviation fuels only increased moderately to 1,628,425 tons, while kerosene consumption remained at practically the same level as for 1958, the increase recorded for burning oil being offset by a fall in consumption of vaporising oil. Deliveries of propane and butane continued to rise and reached a total of 125,252 tons, compared with 89,125 tons in 1958, while bitumen consumption reached a record figure of 990,927 tons. Miscellaneous products, largely consisting of chemical feed stocks, increased from 944,327 to 1,441,676 tons. The growth in oil demand may be noted from the returns quoted for 1938, 1948 and 1953, which were 8,990,686 tons, 12,766,025 tons and 19,002,695 tons respectively. The increased activity of the refining industry is indicated by an output of 2,391,722 tons in 1938, 4,461,567 tons in 1948 and 39,136,237 tons in 1959.

Shipbuilding Returns

The Merchant Shipbuilding Returns for the first quarter of 1960 have been issued by Lloyd's Register of Shipping and show that, in Great Britain and Northern Ireland, the work in hand included 269 ships of 1,960,651 tons gross, the lowest figure since June, 1950. During the quarter the tonnage commenced, launched and completed was sixty-two ships of 228,370 tons, sixty-two ships of 334,197 tons, and sixty-nine ships of 300,921 tons respectively, there being a pronounced fall in the tonnage commenced. Oil tankers under construction totalled fifty-five ships of 990,226 tons gross, or 50·5 per cent of the total tonnage. For registration abroad, there are thirty-one ships of 200,516 tons which represents 10·2 per cent of the tonnage being built and compares with a peak export figure of 825,745 tons, or 40·4 per cent, in September, 1950. Work in hand abroad amounted to 1174 ships of 7,406,323 tons gross, excluding China, East Germany and Russia. Ships commenced, launched and completed during the quarter respectively amounted to 383 ships of 1,594,243 tons, 376 ships of 1,545,755 tons, and 359 ships of 1,749,212 tons. Export tonnage totalled 3,112,544 tons, or 42·0 per cent of the total under construction. Of the tonnage being built, 194 ships of 3,661,934 tons, or 49·4 per cent, were oil tankers. Throughout the world, 1443 steam ships and motor ships of 9,366,974 tons were under construction, of which 20·9 per cent were building in Great Britain and Northern Ireland. Of this total, oil tankers accounted for 249 ships of 4,652,160 tons gross, or 49·7 per cent. Of the tonnage under construction, 5,213,816 tons, representing 55·7 per cent, were building under the supervision of Lloyd's Register.

Iron Ore

A new company, British Ore Investment Corporation, Ltd. (B.O.I.C.), with a share capital of £5,000,000, has been formed by nine of the principal British steel making companies using imported ore, and by British Steel Corporation, Ltd., an investment holding company associated with the British Iron and Steel Federation. The main object of B.O.I.C. is to hold investments in overseas ore-mining companies, a function formerly undertaken for the British steel industry by British Steel Corporation, Ltd., alone.

The principal shareholders in B.O.I.C. are British Steel Corporation, The Steel Company of Wales, Ltd., Colvilles, Ltd., South Durham Steel and Iron Company, Dorman Long (Steel), Ltd., John Summers and Sons, Ltd., Richard Thomas and Baldwins, Ltd., Consett Iron Company, Ltd., Guest Keen Iron and Steel Company, Ltd., and The United Steel Companies, Ltd. Amongst other investments, the new company has taken over British Steel Corporation's 20 per cent interest in Société des Mines de Fer de Mauritanie (M.I.F.E.R.M.A.), a £60,000,000 project in French West Africa, the capital of which (equivalent to about £19,000,000) is being subscribed together with French, Italian and German interests. The ultimate intention of M.I.F.E.R.M.A. is to produce 6,000,000 tons of iron ore a year. The ore will be transported on a specially constructed railway over a distance of about 400 miles to a port to be built near Port Etienne, in Mauritania. B.O.I.C. has also taken over the 30½ per cent British participation in Compagnie Minière de Conakry, a company mining ore in the Republic of Guinea.

Unemployment

The Ministry of Labour says that, on April 11, there were 391,182 people registered as unemployed in Great Britain, 10,084 of whom were temporarily stopped. Between March 14 and April 11, the number of unemployed fell by 22,006, the wholly unemployed figure declining by 21,000. Expressed as a proportion of the estimated total of employees, the April unemployment figure was 1·8 per cent. In March it was 1·9 per cent, and in April last year 2·4 per cent. Unemployment between March and April fell by about 31,000 among adults but rose by 9000 among boys and girls. The number registered as unemployed in Northern Ireland on April 11 was 35,600 (7·5 per cent of the estimated number of employees).

The employment exchanges in Great Britain filled 151,000 vacancies in the four-week period ended April 6. The number of vacancies notified but still unfilled at that date was 306,000, which was 39,000 more than at the beginning of March.

Electronic Components Exports

Production of electronic components during 1959 was 2400 million items, valued at £120 million. This represented a rise of 20 per cent over 1958 (1950 million components valued at £100 million), the steepest annual rise since 1955. The annual report of the Radio and Electronic Component Manufacturers' Federation states that the main increase was among components used for radio and television receivers, accounting for 43 per cent of the total, but more than 30 per cent in addition were sent to manufacturers of capital goods, and a further 14·6 per cent were exported directly. Exports of components and sound-reproducing equipment were valued at over £22,500,000, a rise of £1,500,000 (or 7 per cent). The value of components exported direct (a further large number are incorporated in finished products) was over £11,000,000, a rise of 13·4 per cent in the year, and of sound-reproducing equipment, nearly £11,500,000, 2·5 per cent up. The United States was again the biggest buyer of sound-reproducing equipment (over £5,000,000, a rise of nearly £700,000 in the year) and Australia was again the principal market for components (nearly £1,340,000 an increase of £350,000). The report states, however, that imports of foreign radio and electronic products—mostly from the Netherlands, West Germany and the U.S.A.—give rise to growing concern, and are increasing at three times the rate of exports. Audio products imported in 1959 were valued at £5,247,000, including tape recorders and decks at £2,770,000.

PERSONAL AND BUSINESS

Appointments

ALDERSLEY ENGINEERS, Ltd., announces the appointment of Mr. J. H. Hislop as a director of the company.

GEORGE KENT, Ltd., announces the appointment to the board of directors of Mr. John F. Willsher, general works manager.

MR. M. H. BEATTIE, M.I.E.E., has been appointed assistant sales manager (power cables) of British Insulated Callender's Cables, Ltd.

BRITISH RAILWAYS, LONDON MIDLAND REGION, has announced the appointment of Mr. M. C. Purbrick, A.M.I.C.E., as district engineer, Derby North.

MR. C. H. OFFORD, general manager of the Newhouse (Lanarkshire) factory of Honeywell Controls, Ltd., has been made a director of the company.

MR. BERNARD ALFRED WICKS has joined the board of directors of Wipac, Ltd., as works director. He will be in control of the manufacturing organisations within the group.

MR. H. B. CAMPBELL, A.M.I.Mech.E., has been appointed assistant chief project engineer to the Central Electricity Generating Board's southern project group at Finchley, in succession to Mr. W. H. C. Pilling.

MR. LEONARD G. OXFORD, managing director of Simmonds Aerocessories, Ltd., and Firth Cleveland Instruments, Ltd., has been elected president of the South Wales branch of the National Union of Manufacturers.

THE MINISTRY OF AVIATION announces the following appointments: Mr. Eric Bairdstow Carter has been appointed director of engine production; Mr. John Dickens Clare has been appointed director of guided weapons research and development (air) in succession to Air Commodore H. B. Wrigley.

THE WALLSEND SLIPWAY AND ENGINEERING COMPANY, Ltd., states that Mr. John A. Bolt, A.M.I.Mech.E., has been appointed manager of the oil burner department in succession to Mr. A. M. Wood who is to retire on May 31, after completing over fifty years' service with the company.

LANCASHIRE DYNAMO NEVELIN, Ltd., announces that Mr. V. W. Press has resigned as sales director to take up a similar appointment with the Limit Engineering Group, where he will be responsible for implementing the sales expansion programme following the acquisition of an additional factory at St. Albans.

THE MINISTRY OF HOUSING AND LOCAL GOVERNMENT has announced the appointment of Rear-Admiral St. John Micklethwait, Mr. Duncan Alexander and Mrs. R. Rees as members of Cwmbran Development Corporation. Rear-Admiral Micklethwait will become chairman of the Corporation on May 1 in succession to Lady Rhys-Williams, who has resigned.

THE BRITISH PETROLEUM COMPANY, Ltd., has announced that Sir Neville Gass, having reached normal retirement age, is relinquishing his appointment as chairman of the company on June 30. The Hon. M. R. Bridgeman has been appointed chairman, and Mr. J. M. Pattinson, deputy chairman. It is intended to appoint Mr. M. A. L. Banks to fill the vacancy on the board caused by the retirement of Sir Neville Gass. All these appointments will be effective from July 1, 1960.

ASSOCIATED ELECTRICAL INDUSTRIES, Ltd., heavy plant division, has announced the following appointments: Mr. N. R. D. Gurney, M.I.E.E., has relinquished the position of manager, large electrical machine sales (Manchester), but will remain a member of the executive of heavy plant division. Mr. I. A. Ferguson, M.I.E.E., hitherto manager, large electrical machine sales (Rugby), has assumed responsibility for the entire department, and Mr. J. Cannell, A.M.I.E.E., has been appointed assistant manager.

SIR NORMAN KIPPING, director general of the Federation of British Industries, and MR. LEWIS T. WRIGHT, general secretary of the Amalgamated Weavers' Association, have accepted the nomination of the British Productivity Council to be patrons of the Centre for Interfirm Comparison. Among those who have accepted nomination by the British Institute of Management are Sir Hugh Beaver, managing director of Arthur Guinness Son and Co., Ltd., Mr. J. E. Currie, managing director of Stevenson, Jordan and Harrison, Ltd., Mr. Edwin Fletcher, secretary, production department of the T.U.C., and Sir Nutcombe Hume, chairman of the Charterhouse Group of Companies.

Business Announcements

JOHN BROWN AND CO., Ltd., and STANDARD TELEPHONES AND CABLES, Ltd., announce that they have purchased major interests in Auto-Stackers, Ltd.

W. B. CULL AND SONS, Ltd., will vacate its Tennant Street, Birmingham, premises on May 7, and move to a new factory at Powke Lane, Old Hill, Staffordshire.

UNION CARBIDE, Ltd., announces that its alloys division, Glasgow office, is now at Cornhill House, 144, West George Street, Glasgow, C.2 (telephone, Central 6454).

MICHELIN TYRE COMPANY, Ltd., states that its branch office and depot in Liverpool is now established in a new building at 57, Hill Street, Liverpool, 8 (telephone, Royal 5112-3).

MR. F. C. BRABY, chairman of the Fredk. Braby Group of Companies, is visiting Canada and the U.S.A. in connection with various pending licensing arrangements for Group products.

RATHDOWN INDUSTRIES, Ltd., 17, London Road, Ascot, Berks, states that its factory will close for the annual holiday at 5 p.m., Friday, July 22, and re-open at 8.30 p.m., Tuesday, August 9.

THE ROYAL SOCIETY FOR THE PREVENTION OF ACCIDENTS, industrial safety division, states that the Sir George Earle trophy for industrial safety achievement has been awarded this year to Associated Electrical Industries (Manchester), Ltd.

OPTOSHIELD, Ltd., 146, Clerkenwell Road, London, E.C.1, has been formed to market all articles manufactured by the Fleming B.A.O. Group of Companies which are intended for industrial consumption. Mr. C. J. Williams has been appointed general sales manager of the new company.

NEWMAN INDUSTRIES, Ltd., Yate, Bristol, is to erect three new buildings, each covering 10,000 square feet, in the southern region of the U.S.A. These will be at Atlanta, where the company's new south-regional office is to be set up, and at Savannah and Memphis, where sub-distribution centres are to be established.

GEORGE WAILES AND CO., Ltd., 382-388, Euston Road, London, N.W.1, announces that these works will close down on Saturday, April 30, and will not re-open. The premises will be vacated by Friday, July 8. Mr. Rex Wailes' address will be Davidge Cottage, Knotty Green, Beaconsfield, Bucks (telephone, Beaconsfield 1088).

THE FAIREY COMPANY, Ltd., states that in consequence of the sale of its subsidiary company, Fairey Aviation, Ltd., to Westland Aircraft, Ltd., its address is now Woodlands Park, Iver Heath, Bucks (telephone, Uxbridge 8377). The London office of the company remains at 24, Bruton Street, W.1 (telephone, Mayfair 8791).

SPERRY GYROSCOPE COMPANY, Ltd., Brentford, Middlesex, has now commenced production of the CL.11 series of "Gyrosyn" compasses, incorporating the "Rotorace" principle. This latest compass is currently being manufactured by Sperry in the U.S.A. and Canada. The construction of the rotor gimbals and the introduction of the "Rotorace" principle permit random gyro wander to be kept well below 1 deg. an hour, a tenfold improvement over compasses in general service to-day. The "Rotorace" technique eliminates random torques in conventional gimbal bearings by rotating the outer races in alternating directions, the two bearings of a pair being motored in opposite senses.

ROYSTON INSTRUMENTS, Ltd., of Byfleet, Surrey, and LOCKHEED AIRCRAFT SERVICES, Ltd., of Ontario, California, have signed a joint marketing agreement for the "Midas" range of Magnetic Tape Data Recording equipment. Lockheed Aircraft Services has agreed to handle the full range of "Midas" data recorders and data reduction equipment throughout the Western Hemisphere and Australasia. This agreement follows closely on the Federal Aviation Agency regulation requiring all turbine aircraft in the United States, flying at heights of over 25,000ft, to carry flight recording equipment. The new range will supplement the Lockheed Aircraft Services 109C flight recorder, already delivered or on order for nearly 400 American jet aircraft. The LAS 109C was developed to meet the F.A.A. mandatory requirement for a crash recorder only.

Contracts

DE HAVILLAND ENGINE COMPANY, Ltd., has received from the Ministry of Aviation a contract for a large number of 1000 h.p. "Gnome" (General Electric T-58) engines for retro-fitting in Royal Air Force Westland "Whirlwind" helicopters and for installation in Mk. 10 "Whirlwind" production. Two of these engines will be fitted to the Mk. 2 version of the Westland "Wessex."

Miscellanea

DRILLING FOR OIL.—We are informed by the Shell International Petroleum Company, Ltd., that the mobile underwater oil-drilling platform "Triton" is to make three drillings in 1961 off the coast of South Holland at sites selected on the results of a seismic exploration now in progress.

FISHING BOAT POWER UNITS.—It has been announced that the Perkins three-cylinder P3/144 (M) and the four-cylinder Four 270 (M) marine diesel engines have been approved by the White Fish Authority for installation in fishing boats, under their grants and loans scheme, following tests of both engines under working conditions at Teignmouth and Holyhead.

ENGINEERING GRADUATES' ASSOCIATION.—The University of Nottingham has announced the formation of an Engineering Graduates' Association open to all engineers who graduated from either the University College or the University. Further particulars can be obtained from the joint honorary secretaries, Mechanical Engineering Department, University of Nottingham, University Park, Nottingham.

WAGON-EMPTYING GRAB.—It is claimed by Michael and Partners, Ltd., Chesterfield, that its new 1¼ cubic yard grab will empty a standard British Railways steel wagon so completely that hand trimming is eliminated. When fully open it spans 7ft 11½in across the jaws and hence fits squarely within a wagon 7ft 11½in wide: when used with wooden trucks, the grab must be entered partly closed but the jaws remain outermost. Since it must be introduced to the wagon deliberately, the grab is designed to close with a digging action.

TRAFFIC ENGINEERING JOURNAL.—The publication in May of the first issue of a new monthly journal called *Traffic Engineering and Control* has been announced by the publisher, Printerhall, Ltd., 34–40, Ludgate Hill, E.C.4. The purpose of the new journal, it is stated, is to "draw attention to the contribution that the application of the techniques and methods of traffic engineering can make to improvement of the ever-worsening conditions on the roads." The journal will be edited by Mr. Ernest Davies, a former chairman of the Parliamentary Labour Party Transport Group.

ALUMINISED ASBESTOS CLOTH.—An aluminised asbestos cloth has been developed by the Turner Brothers Asbestos Company, Ltd., of Rochdale, to provide a fire-proof cover cloth which is strong, durable and impermeable to moisture and has a finish which compares favourably with plastic and decorative finishes. It achieves thermal economy by heat reflection; it is easily fitted over primary pipe insulation and can also be fabricated into mattresses. The cloth is available in five qualities weighing from 23½ oz to 44 oz per square yard, and is supplied in 45-yard long rolls 40/42in wide.

RAIL TRANSPORTER FOR MOTOR CARS.—It will be recalled that a number of double-decked vehicles for transporting motor cars by rail have been built by Newton Chambers and Co., Ltd., Thorncliffe, Sheffield, for M.A.T. Transport, Ltd. (see illustration on page 185, January 31, 1958). With these open transporters the cars are exposed to the severely aggressive environment of a railway system, and therefore fourteen somewhat similar vehicles ordered by British Railways (Eastern Region) for the car-sleeper service between King's Cross and Perth will be enclosed. The bodywork will be of glass-fibre-reinforced plastic, through coloured in B.R. maroon with translucent panels in the roof, moulded into flanged panels and bolted together; this is claimed to be the first time a complete, if unstressed, body for a rail vehicle has been made in glass fibre. The closed transporters will carry five cars up to 12½ tons weight, instead of 10 tons on the original vehicles, and be 64ft long instead of 60ft 8½in. The hoists for emplacing cars on the lower deck will be power-instead of hand-operated.

CONTINENTAL AFFAIRS

by Our Continental Editor

German Industries Fair at Hanover

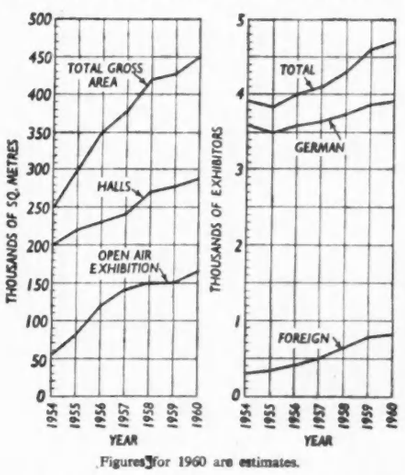
No. 1

ON April 24, the German Industries Fair opened at the Hanover Exhibition Ground, and will continue until May 3. At this, the major industrial fair on the Continent, the area rented by exhibitors has again increased, and now amounts to 447,000 square metres, of which nearly 290,000 square metres is hall space. The latter has been enlarged by 10,000 square metres since last year, with benefit mainly to the branches of precision mechanics, optical instruments, ironmongery, and industrial refrigeration. The open air exhibition has been increased from 150,000 square metres to 162,000 square metres. Fig. 1 shows the growth of the Fair since 1954.

With 836 firms out of 4791 exhibitors at the 1960 Fair, the foreign contingent has doubled since 1956. This trend is still continuing, as evidenced by the waiting lists which include some of the most important fields, and are the principal reason for the continued expansion.

The leading country among foreign exhibitors is France with 177 firms (150 in 1959), followed by Austria with 120 (110), the United Kingdom with 96 (90), the U.S.A. with 91 (92), and Switzerland with 83 (75) firms. Sweden has 67 (60) participants, the Netherlands have 55 (50), Italy has 46 (38), Belgium 34 (40), and Denmark 28 (28). The Eastern bloc is represented by five export agencies, each of which is acting on behalf of large numbers of individual undertakings, often up to 100. Altogether twenty-four European and overseas countries are taking part. It should be pointed out, however, that at Hanover there are no national pavilions, and all firms participate as individuals in their respective sections.

An analysis according to branches shows that in one special section (tools), foreign participation has already exceeded 30 per cent (60 out of 186 exhibitors), whilst in mechanical engineering with its twenty-three sub-groups—the strongest industrial section of the Fair—foreign firms account for 21 per cent of the total (294 out of 1403). In the electrical field (twenty-eight sub-groups), where 1257 firms are taking part, 210 come from abroad. Foreign interest is further exemplified by the industrial supplies section (10 out of 50), building plant and machinery (20 out of 101), office equipment and supplies (103 out of 499), and heating plant (14 out of 67). This is followed by glass (18 out of 101), precision engineering and optics (21 out of 155), porcelain and ceramics (33 out of 159), jewellery (19 out of 208), and chemistry and plastics (11 out of 100).



Figures for 1960 are estimates.

Fig. 1—Growth of exhibition area and participation, 1954-1960

Expansion Plans

Since the currency reform of 1948, a total of DM.100·5 million has been invested in the Hanover Exhibition grounds, and further expansion involving DM.20,000,000 to DM.30,000,000 is considered to be still necessary. The final development will take place mostly in the northern part of the area. By 1963-64 it is planned to add a new North Entrance, an export exchange, a hall with 20,000 square metres of floor space, 30,000 square metres open exhibition area, buildings for press services and reception of foreign visitors, a congress hall, including a restaurant for 1200 persons, a new hall for the special Industrial Design Exhibition, new administrative offices, and various alterations in the siting of rail tracks, unloading facilities, workshops, and stores.

The Hanover Exhibition Grounds are owned and operated by the Deutsche Messe-und Ausstellungs-A.G., which is controlled by the Land of Lower Saxony and the City of Hanover. An increase of DM.4,000,000 in the present share capital of DM.18,760,000 during the next three years is being forecast.

In its final state, the German Industries Fair will probably occupy a gross area of 990,000 square metres. The present open air exhibition of 162,000 square metres is to be increased to 200,000 square metres, the hall space from 285,000 to 310,000 square metres.

As usual, a number of special meetings are being held in conjunction with the Fair. Mention may be made of the Congress of the Building Industry which will take place on May 2 and 3. On the first of these days, the theme is "Industrialisation of building—prefabrication as a principle of construction"; while the second day will be devoted to "Power and heating technology in building."

A meeting was held on April 26 by the Association of German Post Office Engineers and another to-day by the Association of German Railway Engineers.

A few words may be said about this year's participation in some of the principal product groups.

Electrical Industry

With 1257 manufacturing companies (1959 : 1215) the electrical industry occupies second place at Hanover after the mechanical engineering industries with over 1400 exhibitors. Its twenty-eight sub-sections, which cover the whole gamut from heavy generating equipment to electronics and domestic appliances, are housed in Halls 10, 11, and 13, in the five-storey Pavilion 12, and on the adjoining open space. Thus, the electrical side of the Fair covers 104,000 square metres of hall space and some 8000 square metres of open area. In addition, certain specialist companies are showing in the halls of other, related, exhibition groups, for example, manufacturers of electrical tools who are exhibiting as part of the tool industry, and manufacturers of electrical office equipment who with makers of other office equipment are housed in the 33,500 square metres in Hall 17. Electrical machinery manufacturers number 98 companies, and those making switchgear, installation materials, heating and domestic appliances, electrical instruments, and low-tension material, number over 100. The exhibition of light fittings, installed in Pavilion 12 since 1958, this year shows

CONTINENTAL AFFAIRS *(Continued)*

the products of 154 companies, on a floor space of approximately 19,000 square metres. Radio, television and gramophone industries occupy the 10,000 square metres basement of Hall 11. Of the 210 foreign companies, 72 are from France, 42 from Austria, 21 from Switzerland, and 20 from Great Britain.

Internal Combustion Engines

This exhibition, housed on 7300 square metres in Hall 3 (where there is also the French Atomic Energy Exhibition), comprises seventy-one (seventy) firms, of whom twenty-one (fifteen) are from abroad. Foreign exhibitors—British, American, French, Austrian, Italian, Dutch and Swedish—occupy 950 square metres. An information centre of the V.D.M.A. provides documentation about the entire prime mover field in the Federal Republic, including steam engines, and steam and water turbines which will be exhibited again next year in alternation with the internal combustion engines.

Woodworking and Timber Machinery and Equipment

One of the most considerable sectors of the Hanover Fair is that devoted to woodworking machines and plant for the production of timber, as well as auxiliary equipment and accessories. A total of 17,635 square metres comprising Halls 8 Centre, 8 South, and the eastern portion of Hall 8 North is occupied by firms from this field. The number of exhibitors has increased over last year's by sixteen to 247, while the exhibition area is larger by 1600 square metres. Foreign firms number fifty-eight (forty-nine) and are led by Switzerland, Italy, the U.S.A., and France.

Aeronautical Exhibition

Facilities for the Aeronautical Show, which again takes place at Hanover Airport, have been greatly improved. The exhibition hall has been enlarged from 2800 square metres to 4000 square metres, and the adjoining open area of 60,000 square metres has been surfaced, partly with concrete and partly with bitumen. New road and rail connections have been installed as well as additional parking space for 2200 motor-cars and buses. The number of exhibitors this year is 172 (1959 : 107), and over fifty aircraft by German and foreign makers are being shown.

Last year exhibitors' aircraft carried out some 1400 take-offs and landings during the ten days of the Hanover Fair. In addition to regular airline services, some 200 special flights were routed to Hanover. With its main take-off runway lengthened by 360m to 2340m, the airport can be used by the largest present-day jet airliners, although crossings of the Atlantic still require intermediate fuelling stops.

Fried. Krupp

In the pavilion of Fried. Krupp, Essen, is being shown the full-scale replica of the diving sphere used in the recent epoch-making dive by J. Piccard and D. Walsh. On January 23, the Swiss scientist Jacques Piccard and Lieutenant Don Walsh of the U.S. Navy reached a depth of 10,910m in the Mariana Trench, the deepest known point on earth. This descent had been preceded by trial dives to 5668m in November, 1959, and 7300m early in January. The vehicle employed was the bathyscaph "Trieste," developed by Professor Auguste Piccard, the father of Jacques Piccard. The bathyscaph principle, it will be recalled, is that of the balloon; a pressure-resisting gondola for the crew is suspended from an envelope filled with petrol which makes it lighter than water. Since the external and internal pressures are allowed to equalise, the envelope requires only to be sufficiently strong to resist surface waves, but does not have to support the water pressure at depth. The gondola is basically a sphere, this being, weight for weight, the strongest possible configuration. The dive is begun by flooding auxiliary air compartments, and the descent, which becomes faster with depth as the petrol is compressed, is slowed down by jettisoning steel shot carried as ballast. Later, by jettisoning more ballast, the bathyscaph is made to ascend. About 1 ton of ballast is required per 1000m of depth. The total of approximately 11 tons was carried in two bunkers fore and aft. A solenoid around the discharge duct of each bunker retains the ballast by applying a fail-safe magnetic constriction.

A dive to 3150m to the bottom of the Tyrrhenian Pit, off Naples, was accomplished by the Piccards on September 30, 1953. This was surpassed the following year, when Lieut.-Commander Houot and Engineer-Officer Willm dived to 4050m off Dakar in the French Navy's bathyscaph "FRNS-3" on February 15.

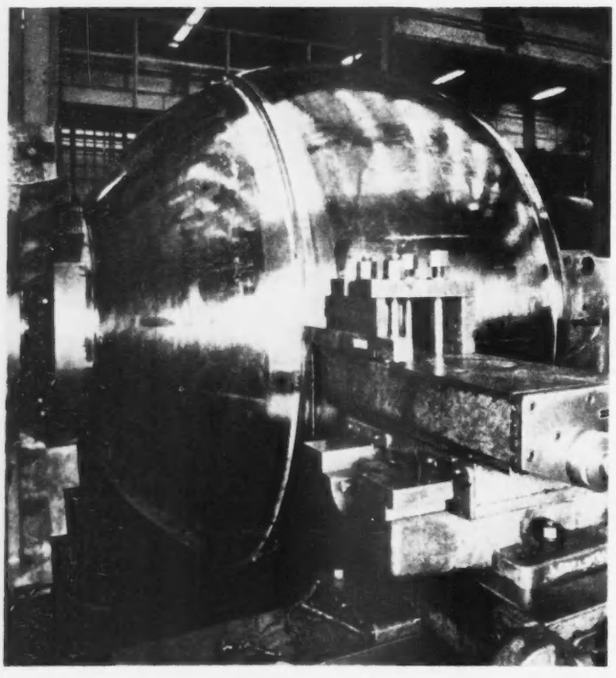


Fig. 2—Finish machining of bathyscaph sphere

For the recent dive into the Mariana Trench, a new pressure sphere was designed and produced by Fried. Krupp, in collaboration with Professor Piccard, between November, 1958, and March, 1959. Water pressure at the depth to which the descent was made was 1152 atmospheres. (The pressure depends on compressibility, salinity and temperature, as well as depth.) This meant that the spherical shell (Fig. 3) which had an external diameter of 2·18m, was subjected to a total force of 172,000 tonnes. With a wall thickness of 12cm, the sphere was compressed 3·7mm.

The material chosen for the 12-ton sphere

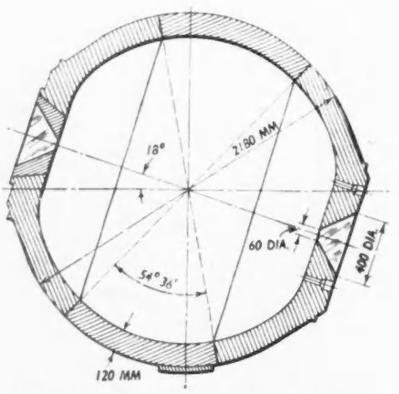


Fig. 3—Sectional elevation of bathyscaph sphere

was vacuum-cast electro chromium-nickel-molybdenum steel, heat-treated to 104 kg per square millimetre ultimate strength, 92 kg per square millimetre yield point, and 15·4 per cent ultimate elongation. The nominal analysis was C 0·35, Si 0·25, Mn 0·40, P 0·035, S 0·035, Ni 1·5, Cr 1·5, Mo 0·25 per cent. By contrast with earlier spheres which consisted of two hemispherical forgings, Krupp employed three forgings, which, by using special forge tools such as a shaped mandrel, enabled an optimum direction of the grain to be obtained. The outer surfaces were machined on a copy-facing lathe, the inner surfaces on a vertical boring mill with the aid of a spherical turning attachment. Ultrasonic and magnaflux tests were repeated several times to verify the absence of all flaws. Pressure tests were carried out on a 1 : 20 scale model which was subjected several times to 1500 to 2100 atmospheres in a pressure vessel. It finally imploded at 2200 atmospheres, the failure appearing to be initiated by curling of a joint.

The three component sections of the sphere are not welded but glued together, using "Araldite 103" with hardener "951," made by C.I.B.A., Basle. In order to avoid shear stress, the joints are not flat but conical, and directed towards the centre of the sphere, where the faces subtend an angle of about 27 deg. at the equator. A high degree of accuracy of the order of 5 microns was required, both micro- and macro-geometrically, so as to make sure the joints would be tight. This accuracy was achieved by machining all joints in turn on a new vertical boring mill, (Fig. 2) using the same setting, while locking all movements which were not needed.

At the ends of its axis the sphere has two major openings, one for the door and one for the observation window, and as these openings weaken the shell the wall thickness is increased to 180mm.

The door is conical and carefully lapped to its seating; when in use, a rubber strip is placed over the joint on the outside to make quite sure the door is tight. Its weight of 200 kg is counterbalanced by springs in all positions. The door carries a second observation window similar to the first, this window giving a view of the sea through the transparent plastic back of the access shaft. Both windows are of transparent plastic ("Plexiglass M222"), but the shape of a squat truncated cone. Because of the great thickness of 180mm, they had to be made from two cast plates stuck together.

The wall round the lower window is pierced by twelve smaller holes, eight of which are for electric cables, two for ventilation when surfaced, and two for manometer connections. These last which had to be kept open all the time, were made as small as possible, and turbulence chambers were fitted to prevent the ingress of a lethal jet should one of the manometers be fractured. The remaining holes were closed with conical plugs of "Plexiglass."

(To be continued)

French Suspension Railway

A group of French firms has developed an electric suspension railway intended especially for passenger transport in large cities, and with this end in view designed with special regard to high speed and carrying capacity, low noise level, and compact track construction. An experimental line of 2km length was recently inaugurated at Chateauneuf-sur-Loire. The car is suspended from two rubber-tyred electric bogies running inside a horseshoe-shaped box section girder. It can attain 100km per hour, with accelerations up to 2m per second per second, and can carry up to 123 passengers. The minimum radius of curves is 30m.

THE idea of carrying vehicles suspended from an overhead track is almost as old as the railway itself, and in the course of the years a large number of inventions sought to embody this principle in one form or another. In the rapidly growing and increasingly congested cities of the nineteenth and twentieth centuries the saving in space at ground level seemed particularly attractive, as was the isolation from other transport, with its promise of increased safety and speed. However, the unsightliness of their track structures and their general noisiness never allowed suspension railways to become popular, with a few exceptions such as at Wuppertal and Dresden-Loschwitz where suspension systems have been in satisfactory service for upwards of fifty years. Such local successes as were achieved in the earlier days principally came about due to the absence of practicable alternatives. At Wuppertal, for instance, in an elongated agglomeration of townships in a narrow valley, with overcrowded, steep streets, traffic conditions at the turn of the century already resembled those now becoming familiar everywhere. The line of the river was the only practicable route left for the tramway that was being proposed. In the teeth of much opposition, which based itself, both on aesthetic considerations and on the inconvenience to the occupiers of riparian properties, it was decided to construct a suspension tram, with portal supports spanning from one bank to the other. Now in its sixth decade, the system has given satisfactory service from its inception, without a single major accident.

More recently, prototypes of various designs have been built in a number of countries in Europe and overseas, such as the Frazer-Bennie (Great Britain, 1925), the Alweg (Germany), Mayer (Argentine), "Skyway" or "Trail Blazer" (Houston, U.S.A., 1957) as well as a Japanese system in 1958.

Recently, a design originated by a group comprising a number of leading French firms made its public début at Chateauneuf-sur-Loire, where a full-scale demonstration line 2000m long has been put into operation.

This suspension railway, called the "Overhead Suspended Rapid Transit," incorporates several novel aspects, while other features had already proved their worth in practice. These, it is stated, have helped to overcome the principal objections to the overhead system in towns; the simple appearance of the supports and track (Fig. 1) lessens the encumbrance of the skyline. Smooth and almost noiseless running is obtained by means of electric bogies running on pneumatically-tyred wheels in the manner of Châtelet-Les Lilas line (Line No. 11) of the Paris Métro (opened 1955; prototype, 1951). Lastly, the idea of the S.N.C.F.'s "pendulum car"* has been adopted to incline the carriage in the curves which may attain a minimum radius of 30m. The demonstration carriage can seat thirty-two passengers and has folding seats for twenty-four more. With these folding seats up, a total of ninety-one standing passengers can be carried. Speeds of 90km per hour are attained in 40 seconds under full load, and the maximum speed is quoted as 100km per hour. The system is stated to cost three to four times less than an equivalent surface railway.

Track and Supports

About half the total cost is incurred in connection with the overhead track. This takes the basic form of an inverted "U"-girder symmetrical in section about a vertical plane through the centre of the track. This girder is a double-walled, welded-box structure made in standard lengths of 30m, with internal stiffening webs spaced every 3m.

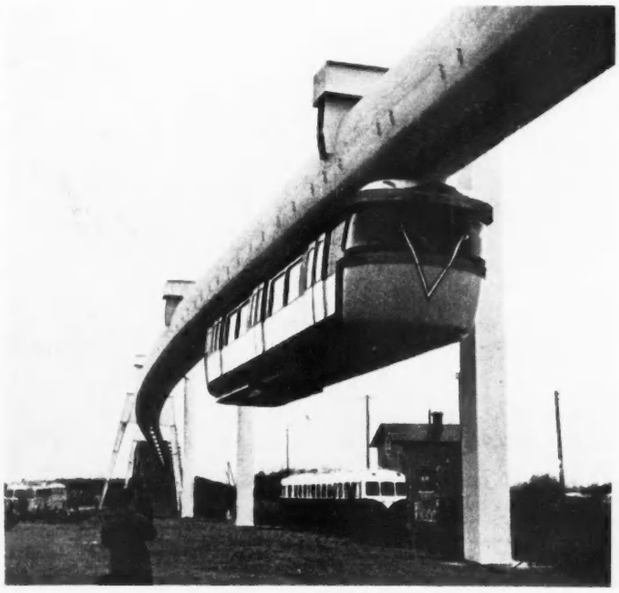


Fig. 1—Overhead railway (prototype). The car is suspended from two rubber-tyred electric bogies running in a hollow box girder track. Projecting bolts on the track are a temporary measure and do not form part of the final design. Recess in car bottom is for later installation of emergency stairs

Our illustration (Fig. 3) shows the section which is very resistant to bending and torsion. The internal form is dictated by the nature and shape of the bogies. The running tracks of 25mm-thick chequer plate are on either side of the central slot at the bottom through which the suspension passes from the bogies to the car. The vertical sides provide tracks for the horizontal guide wheels. A conductor rail fixed centrally to the ceiling of the beam section by means of small insulators supplies d.c. current to the traction motors. Control and signal cables are also housed inside the centre section, which measures 1·3m by 1·3m. In this way the track itself as well as the bogies and the power rail and control lines are protected from the weather. The thickness of the hollow wall ranges from about 0·25m to 0·29m, so that the overall track section measures 1·97m in width and 1·855m in height.

Of great importance is the high degree of adhesion which is achieved by the rubber tyres on a track that is always clean and dry. Tests recently carried out by the firm of Michelin showed (in agreement with American work) the following values for the coefficient of adhesion:

TABLE I—*Coefficient of Adhesion*

Track	Dry surface	Wet surface
Steel plate	0·6–0·7	0·25
Chequer plate	0·7	0·55
Norton sheets	0·8–0·85	0·75
Slifer brick	0·65–0·72	0·53
Asphalt	0·53–0·65	0·51

By the use of chequer plate for the track, it is therefore possible to speed up and slow down at rates limited only by considerations of comfort and personal safety of the passengers. Accelerations actually attained by the system range up to 2m per second per second, while decelerations of 4m per second per second may be used in emergency stops. Gradients of up to 1 in 8 shorten the approaches to any section which it may be desired to lay near ground level (e.g. stations or maintenance workshops), or underground. Approaches to such sections may be as short as 100m to 150m.

The horseshoe shape of the track and its unbroken surface facilitate upkeep, while the fact that the bogies, as it were, run inside a tunnel helps further to reduce the noise level which is already being kept low due to the rubber tyres.

As our illustration shows, the track has a neat appearance. The comparatively light cross section was made possible by the adoption of a pendular suspension, which allows the car to deflect under the action of uneven loading, wind, and centrifugal force in curves, so that the torsion transmitted to the track is kept small. The centre of torsion of the track is in the central plane about 0·6m above the top surface, and the centre of rotation of the suspension lies also approximately at that point.

The standard track, which weighs 800 kg per metre, is designed to be carried on columns which can be placed on the centre-strip of a dual-carriageway road. Measuring 1·8m diameter at the base, the columns, with a wall thickness of 28mm, are set in concrete foundations and filled with reinforced concrete. At the top is fitted a tee-shaped support for a double-track suspension line, or a single bracket if only one track is used. Over narrow streets without central reservations, welded rolled steel portal frames may be erected at somewhat less cost than the columns. These designs have been carried out in ordinary mild structural steel and weldable high-tensile steel.

Curves may have radii as low as 30m, but in curved sections the standard span is reduced to 25m. In special circumstances, such as narrow streets where encumbrance of the sky must be kept to a minimum, it is possible to use an extra-light section made up of two separate "L"-beams in spans of 15m or less. The double-walled section in this case has a height of only 0·6m, and the complete track weighs only 460 kg per metre.

Longer spans than the standard for each shape of section may be achieved by using a filling of prestressed concrete.

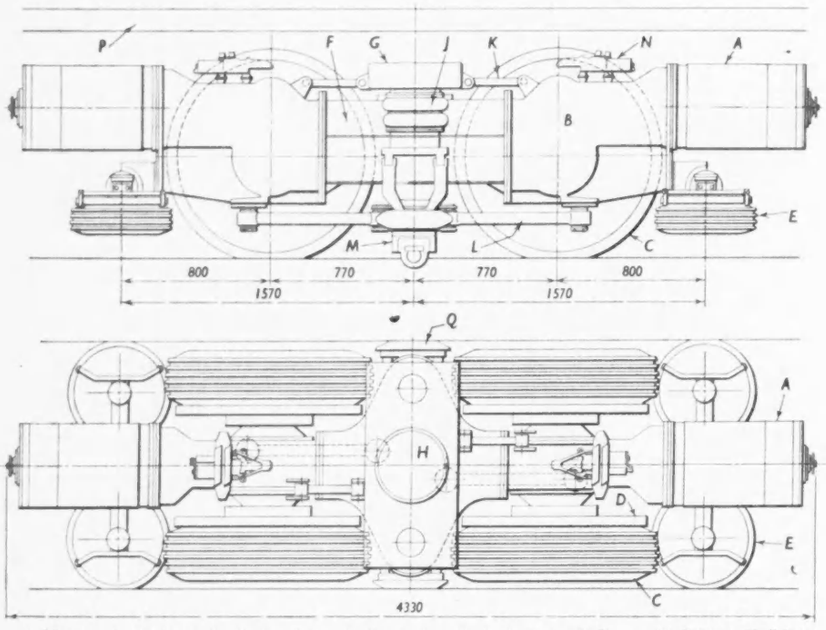
Bogie

Each carriage is suspended from two 200 h.p., twin-axle bogies, which, in addition to being robust, powerful and dynamically stable, are of small section, so as to enable the track to be kept light, and to exploit fully the high adhesion between the rubber tyres and the track surface.

Each bogie (Fig. 2) is powered by two 100 h.p., 750V motors *A*, which are axially arranged and flange-mounted to the reduction gearboxes *B*, the latter in turn being connected by the frame *F*. On the transverse driven shafts of the two-stage reduction gearboxes are mounted the four carrier wheels *C*, fitted with Michelin 1200×20 X tyres with casings incorporating high-tensile steel cords. The tyres are inflated at 9 kg per square centimetre with nitrogen in place of compressed air; nitrogen, it is stated,

* THE ENGINEER, April 12, 1957, page 584.

CONTINENTAL AFFAIRS *(Continued)*



A—Motor ; *B*—Gearbox ; *C*—Carrier wheel ; *D*—Safety rim ; *E*—Guide wheel ; *F*—Frame ; *G*—Bolster ; *H*—Primary suspension ; *J*—Air cushion ; *K*, *L*—Links ; *M*—Ring ; *N*—Pantograph (retracted) ; *P*—Conductor rail ; *Q*—Negative contact shoe.

Fig. 2—Pneumatic-tyred electric bogie

diffuses less easily and there is also a reduction in the fire risk should the tyres become heated. The flexibility of the tyres is about 10mm per tonne. Experience is said to have shown that these tyres can cover a minimum of 150,000km. To guard against the—extremely remote—possibility of a puncture, the wheels are fitted with steel rims *D*, which would enable the journey to be completed at normal speed.

Four horizontal guide wheels *E* are mounted on brackets at the ends of the bogie. These wheels are fitted with Michelin 600 × 9 X tyres inflated at 9 kg per square centimetre. They run on the vertical side walls of the track section and are wedged into the 1·3m gauge to give a compression of 15mm resulting in 400 kg pre-load. A retaining guard is fitted to prevent the guide wheels from falling on the track in case of shaft or bearing failure.

The tubular primary suspension is attached to the bogie by means of a bolster plate *G* carried on two lateral pneumatic cushions *J* and attached to the bogie by the two links *K*. The lower two links *L* support a ring *M* in which the suspension can slide up and down. Links *K* and *L* are mounted in "Silentbloc" rubber mountings. Lateral deflection of the suspension column (not shown in elevation) is possible by sideways movement of the ring *M* against the action of two damper springs (see next section and Fig. 3). Current is obtained from the overhead electric rail *O* by means of two pantographs *N*, the return being through the track by way of the two contact shoes *P*.

The bogie has an overall length of 4380mm and a weight of 4250 kg. Wheelbase and gauge of the carrier wheels are 1540mm and 910mm, respectively.

Suspension

In order to achieve the utmost economy in the design, the lateral forces and torsional moments transmitted to the track must be a minimum. It is one of the functions of the suspension to ensure that this is the case for all conditions of loading ; in addition, the system must be dynamically stable at all speeds within its range of operation, up to 100km per hour and more.

As compared with the S.N.C.F.'s experimental pendulum car, the overhead suspension railway has the advantage of being supported above its centre of gravity, i.e. it is naturally in stable equilibrium. By bringing the virtual centre of rotation of the vehicle as near as possible to the torsional centre of the track, the torsional moment transmitted to the track is kept to a minimum. The high position of the torsional centre, 0·6m above the top of the beam in the central plane of symmetry, means that the virtual radius of rotation is large, and the deflection under out-of-balance loads, centrifugal force, and wind loads up to 85 kg per square metre need not exceed 7½ deg.

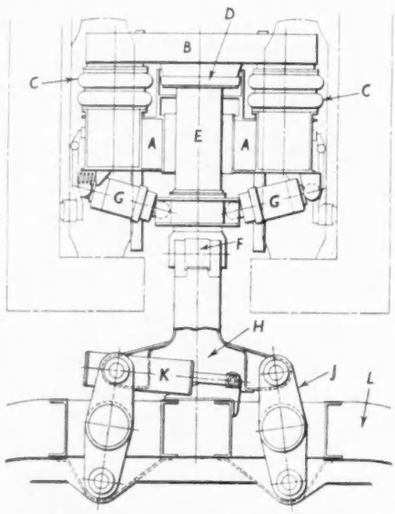
Based upon previous research with the pendulum car, experiments were carried out by the S.N.C.F. with two-dimensional and three-dimensional models to determine the most suitable suspension design.

By tilting the car in the curves, it is possible to counteract centrifugal force and so increase the comfort of the passengers as well as eliminating torsion. On the other hand, it is necessary that the trains should be accurately vertical when entering stations, and that the carriage floors should be level with the platforms at all loads. Fulfilment of these further requirements is an additional function of the suspension.

Reference to Fig. 3 will make clear the layout. Because their tyres are pneumatic, it was not considered necessary to fit the bogie wheels with sprung axles. The car is suspended from the frames *A* of two bogies by a double suspension. The top part comprises a bolster *B* which carries the bogie by means of Firestone pneumatic rubber springs *C* connected to the hollow interior of the bogie frame. The air pressure is 9 kg to 11 kg per square centimetre and is kept adjusted by a valve, the operation of which is governed by the distance between bolster and bogie, so that the same level is maintained irrespective of load. By means of a rubber socket *D*, the vertical tubular column *E* is attached to the bolster, the rubber making possible a lateral deflection of ±4 deg. 20 min. In the longitudinal direction, deflection is resisted by links *K* and *L* (Fig. 2). The lower set of links are attached to a ring-shaped guide in which the column slides, lateral movement being counteracted by "Silentbloc"-mounted damper springs pretensioned to 1000 kg.

Below the primary suspension, to which it is connected by an anti-hunting axle *F*, is the secondary suspension, which consists of a bracket *H* to which the roof frame *L* is attached by means of connecting-rods *J*. The rods, which measure 0·5m between centres, are inclined so as to make their axes intersect with the centre line at the torsional centre of the beam. An oil cylinder *K* moves the frame *L* to right or left. The secondary deflection is ±3 deg. 10 min, making the total deflection relative to the plane of symmetry ±7 deg. 30 min, or ±0·5m.

The roof frame is designed to transmit all coupling and buffing forces and is fitted at the ends with "Scharfenberg" automatic couplings. For safety, it is connected to the bogie with a steel cable passing through the centre of the suspension.



A—Frame of bogie ; *B*—Bolster ; *C*—Pneumatic springs ; *D*—Rubber block ; *E*—Tubular tie ; *F*—Anti-hunting axle ; *G*—Damper springs ; *H*—Bracket ; *J*—Connecting-rods ; *K*—Oil cylinder ; *L*—Frame of car ; *M*—Ring.

Fig. 3—Double system of suspending cars from bogies

While the deflection α of the primary suspension is proportional to the lateral forces acting at any given instant, the deflection θ of the secondary suspension, relative to the primary suspension, is governed entirely by the action of the oil cylinder *K*, which in turn is operated by a control valve depending on α. By making θ proportional to α, the two deflections are added together for maximum effect when running between stations. When on entering a station it becomes necessary to return the car, irrespective of the load distribution, to an accurate vertical position, this may be achieved by making θ proportional to $-\alpha$.

To this end, a control valve is fitted to each of the two brackets *H*. Fig. 4 shows the oil circuit diagram. Each control valve consists of three main components : an "in stations" valve *P*, a "between stations" valve *Q*, and a selector valve *R*, allowing either of these valves to be connected to the operating cylinder. The selectors are themselves hydraulically actuated by a single magnetic valve which is automatically controlled from the track. The lever *S* which operates the spools of valves *P* and *Q* in opposition is pin-jointed to a telescopic bar with socket attached to the bogie frame, so that the angle at the pin-joint and therefore the valve throw due to *S* is proportional to the deflection of the primary suspension. The valve spools slide in movable sleeves *T*, the ends of which are brought out of the main valve casing and joined by a yoke which is held by springs against a cam *U* fitted to the roof frame. The cam shape determines the valve characteristic.

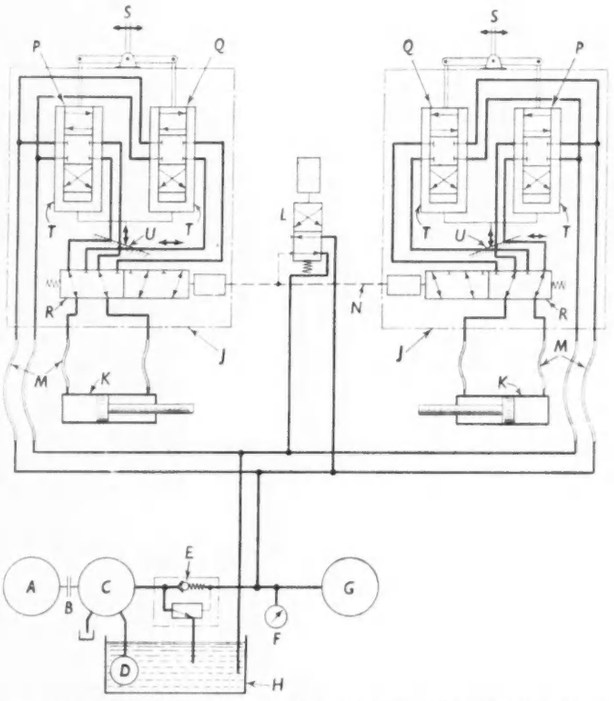
When the primary suspension is deflected, therefore, this deflection actuates the control valve so that, depending on the position of the reflector, pressure oil is admitted to one or the other side of the working cylinder, with the result that the secondary suspension is operated either in the sense of increasing the total deflection (" between stations " operation) or reducing it to zero (" in stations " operation). In either case, the end position is determined by the feedback provided by the action of the cam *U* on the valve sleeves.

Points

For the successful operation of an overhead railway an adequate system of points is essential. The designers of the Overhead Suspended Rapid Transit have devised a layout allowing a minimum radius of the branch track of 30m, so that, e.g. cross-overs, between neighbouring parallel tracks can be made without difficulty.

The point is shown in Fig. 5 from which it will be seen that it comprises three main elements : the diamond *A* which ensures continuity of the running track, and two lateral pieces *B* and *C* for the offside guide tracks, all of which are carried out as steel box girders. The mechanism of *A* includes an electrically-driven oil pump, three single-acting jacks—one at the fulcrum of *A*, the other two at the free end—a double train of rollers powered by a 2 h.p., 1500/750 r.p.m., three-phase synchronous motors, a hydraulic shock absorber at the end of each travel, and magnetic safety interlocks and their related contacts, for checking the position of the point components and operating in conjunction with the signalling system.

To set over the points, the diamond piece is lifted hydraulically and rotated by the rollers, after which it is lowered to its end position. The guide elements are mechanically connected to the diamond and actuated by it. About ten seconds are required to complete the operation.



A—5 h.p., 1500 r.p.m. motor ; *B*—Coupling ; *C*—Pump, 1000 lb per square inch ; *D*—Filter ; *E*—Unloading valve ; *F*—Safety pressure switch ; *G*—Accumulator ; *H*—Tank ; *J*—Main valve ; *K*—Cylinder ; *L*—Magnetic valve ; *M*, *N*—Pressure hose ; *P*—" In stations " valve ; *Q*—" Between stations " valve ; *R*—Selector valve ; *S*—Balance lever ; *T*—Sleeve ; *U*—Cam.

Fig. 4—Circuit diagram of secondary suspension oil circuit

Body

The prototype design now in operation, it is pointed out by the makers, is intended chiefly to demonstrate in actual practice the principles involved, and the layout of the car body, in particular, can readily be altered to suit any specific application.

The demonstration car, which may be seen in Fig. 1, is 17·3m long and has a cross section 3·08m wide by 2·96m high. (Transverse gauge 3·63m for use with underground track, 4·13m for open-air track.) Its light alloy structure weighs 3600 kg, to which must be added 2860 kg for mechanical and electric equipment, and 2000 kg for fittings.

A total floor area of 40·76 square metres is provided, of which 34·4 square metres are for the passengers, while each of the two driving cabs occupies 3·18 square metres. The design floor loading is 675 kg per square metre, allowing for a total live load of 10 tonnes, which may be up to 525mm off-centre. Total lateral wind load may be up to 2100 kg.

Longitudinal forces are transmitted through the roof frame, a maximum buffer impact of 30 tonnes being allowed for. The outer metal skin of the vehicle is designed to support a portion of the loading

Six pneumatically-operated doors are fitted which remain locked during transit even if the air pressure should fail. In such an emergency, one door can be opened by a hand-operated mechanism.

The windows have single fixed panes. Heating and ventilation plant is fitted, maintaining 20 deg. to 24 deg. Cent. in the cabin and giving up to eight renewals of heated air in the winter, and fifteen renewals of unheated air per hour in the summer. Basic heating is by electric radiators placed under the seats and working at traction voltage. A reversible axial-flow fan in the roof, fitted with a heating coil, supplies air through distribution trunking for ventilation and make-up heating, using for this purpose auxiliary current from a 72V battery. The driving cabs are heated by separately controlled radiators. Fluorescent lighting is provided, at a level of 140 lux per square metre 1m above the floor. Emergency lighting is installed and operated from the 72V main battery.

Two or more cars may be made up into trains by using the automatic " Scharfenberg " couplings, installed at roof level at each end, together with automatic junction boxes for the electric control cables.

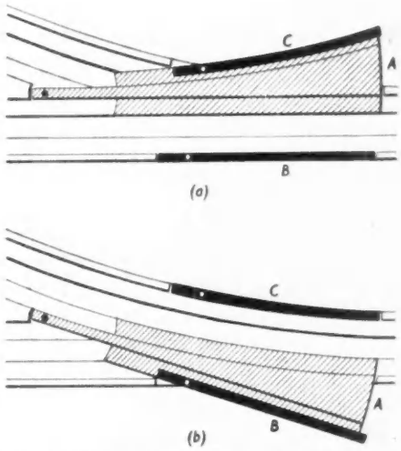
Controls, Braking and Signalling

Speed control of the traction motors is carried out by a servo-driven controller with twenty-nine cam-operated contacts. The relay-controlled 72V servo-motor operates at the rate of eight to twelve notches per second. In addition, there is a commutator for dynamic (rheostatic) braking, as well as a reversing switch, actuated by the main camshaft.

The servo-motor is operated from the driving cab. During starting, a constant torque is maintained by means of an accelerating relay. For rheostatic braking, the motors are connected in pairs, with crossed excitation in series with the starting resistor and braking switch.

For mechanical braking, Westinghouse compressed air brakes are installed, the wheels being equipped with drum brakes.

The line is under the control of a dispatcher who operates points and signals and gives instructions to drivers over the telephone. A fully remote and automatic operation of all trains of a system appears possible at a later stage. At present, driver-operated trains have been adopted in conjunction with the normal automatic block control with track interlocks and three-colour light signals.



(*a*) " Straight ahead " position ; (*b*) " Branch " position. *A*—Diamond with moving gear ; *B* and *C*—Guider actuated by *A* through linkages.

Fig. 5—Principle of point operation

The principal characteristics of the overhead suspension railway are summarised in Table II.

Table II—*Main Data of Overhead Suspended Rapid Transit*

Performance :	
Useful load	10,000 kg
Maximum speed	100km per hour
Maximum acceleration	2m per second per second
Maximum retardation	3·4m per second per second
Track :	
Overall width	1·97m
Overall height	1·85m
Internal dimensions	1·3m by 1·3m
Width of bottom slot	0·5m
Standard span	30m
Standard span (curves)	25m
Minimum radius of curves	30m
Maximum gradient	1 in 8
Weight per metre	800 kg
Bogie :	
Size	4·33m long by 1·3m wide by 1·1m high
Weight	4250 kg
Horsepower	2 × 100 h.p.
Number of motors	Two
Voltage and current	750V d.c.
Number of carrier (driven) wheels	Four
Number of guide wheels	Four
Number of bogies per car	Two
Suspension :	
Deflection of primary suspension	±4 deg. 20 min (±0·25m)
Deflection of secondary suspension	±3 deg. 10 min (±0·25m)
Total deflection	±7 deg. 30 min (±0·5m)
Car :	
Overall dimensions	17·3m by 3·08m by 2·96m high
Weight with equipment	8500 kg
Passenger floor space	34·4 square metres
Total floor space	40·76 square metres
Floor loading	675 kg per square metre
Wind load (total lateral)	2100 kg
Number of doors	Six
Number of seats	Thirty-two plus twenty-one
Number of standing places (with thirty-two seats)	Ninety-one

Participants

The group connected with the development of the Overhead Suspended Rapid Transit (Métro Aerien Suspendu) comprises the following : Société Lyonnaise des Eaux et de l'Eclairage, Paris, and Société Anonyme Française d'Etudes de Gestion et d'Entreprises (S.A.F.E.G.E.) ; Credit Lyonnais ; Banque Française pour le Commerce Exterieur ; Banque de Paris et des Pays Bas ; Banque de l'Indochine ; Aluminium Français ; Société des Forges et Ateliers du Creusot ; Société des Acieries de Pompey ; Société Alsacienne de Constructions Mécaniques ; Etablissements Baudin Chateauneuf ; Compagnie Française d'Entreprises ; Société Générale de Constructions Electriques et Mécaniques Alsthom ; Forges et Ateliers de Constructions Electriques de Jeumont ; Régie Nationale des Usines Renault ; Manufacture Française des Pneumatiques Michelin, Michelin Durin et Cie ; Applications Mécaniques du Caoutchouc, Usines Paulstra ; Etablissements Saxby.

THE AMERICAN SCENE

by Our American Editor

N.B.S. Research on the Mechanical Properties of Metals

To improve the performance of metals and to develop new alloys as they are required by science and technology, a better understanding is needed of the relation of metallurgical structure to the behaviour of metals and of the effects of heat-treatment and temperature extremes on this relation. To provide such information, the National Bureau of Standards has accelerated its research programme on the mechanical properties of metals. The reactions of both conventional metals and super-alloys are observed over a wide range of environmental conditions. Microscopic, X-ray diffraction and induction furnace techniques are used to discover how relatively small changes in lattice structure affect the tensile and yield strengths, ductility, hardness and other properties of metals.

TO-DAY, metals are more important to scientific and engineering progress than at any time in history. Mechanical properties, such as strength and stiffness, permit them to be machined, welded, rolled, pressed, drawn or bent into any desired form. Because of their resilience and toughness, they yield without fracture to shock and vibration. These and similar qualities have achieved for metals a foremost place in the ranks of industrially useful materials. Nevertheless, if metals are to keep pace with contemporary and future technological advances, a better understanding is needed of metallurgical structure and of the influences of heat-treatment and of temperature extremes on this structure. To provide data that will assist in meeting this need, the National Bureau of Standards, of Washington, D.C., has accelerated its programme of fundamental research on the mechanical properties of metals. Instabilities in alloys, changes within the space lattice at the atomic level, surface reactions, the creep process, metal fatigue and all the factors controlling the response of metals to external forces are being investigated in this effort. It is hoped that from information derived experimentally, practical methods will be devised for improving the performance of metals, and for developing new alloys as they are required by industry. To this end, the work on mechanical properties of metals is closely co-ordinated with concurrent N.B.S. programmes in metal physics, chemical metallurgy and corrosion.

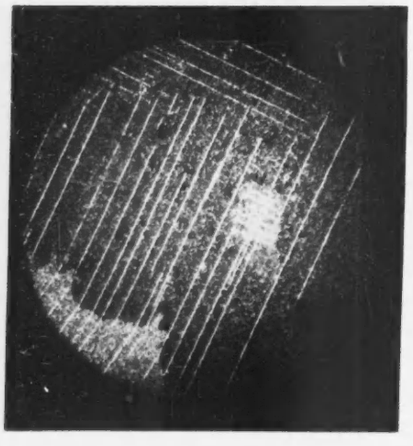


Fig. 1—Surface of an aluminium alloy specimen subjected to reversed torsional loads

Metallurgical Structure

Metal fatigue is the most common cause of mechanical failures in service. This phenomenon may occur in any component or machine part subjected to fluctuating or repeated stresses, sometimes even after many millions of cycles of stress. Hence, much consideration is given to engineering design to increase the useful life of metal parts, particularly in the aircraft industry where the effects of vibrations and other sources of repeated stress must be taken into account. However, in order to achieve optimum design, engineers must be able to predict the behaviour of stressed components with a high degree of accuracy, and this ability requires an understanding of the relation between the structure of metals and the fatigue process.

It is well known that fatigue cracks generally start on pre-existing slip bands within the grains of a metal. However, to study the conditions under which cracks start in commercial metals is difficult, principally because these metals are composed of a large number of small grains. The Bureau has therefore produced aluminium specimens with grains 2mm to 3mm in diameter, so that the behaviour of individual stressed grains could be observed more readily. The accompanying illustration (Fig. 1) shows the surface of an aluminium alloy specimen that has been subjected to reversed torsional loads. The direction of the slip bands (white lines) is different in each grain, even in the small grain near the centre, which is completely surrounded by a grain of a different orientation.

In one study with these specimens, individual grains were found to act independently of their neighbours. There was no evidence that grain boundaries or interaction with neighbouring grains promote cracking. It appeared that the principal factor to be considered in the fatigue-crack initiation of polycrystalline aluminium is the resolved shear stress on the plane of easy slip in the slip direction. This study was sponsored by the National Advisory Committee for Aeronautics, now known as the National Aeronautics and Space Administration.

The results of another study sponsored by this agency showed that the preponderance of fatigue cracks starting at the edges of a metal specimen is caused by the stress pattern, rather than by lower fatigue strength at the edges. In its work on metal fatigue the Bureau has made a study of the factors that influence the fatigue strength of spring wire. The results of this work, which has been carried on under the auspices of the U.S. Army Ordnance Corps, should be of value in efforts to improve the performance and reliability of the springs used in ordnance devices.

Chemical reactions at the metal surface are known to have an important influence on fatigue behaviour. It has recently been observed that if transparent tape is applied to the surface of a fatigue specimen, bubbles form under the tape at about the same time that fatigue cracks are initiated (Fig. 3). These bubbles, caused by gas liberated as a result of surface reactions, are expected to provide a useful means for studying such reactions.

Fig. 2—Microscopic examination of flat specimen on torsional fatigue testing machine

For several years, X-ray diffraction techniques have been used at the Bureau to determine stresses that occur within a metal structure. With these techniques, the lattice strain can be ascertained by measuring changes in interatomic spacing. Because of its selectivity and directionality, X-ray diffraction has advantages over other means for evaluating stresses. In a recent study with iron specimens in which these techniques were used, it was found that plastic deformation of this metal causes residual stresses to develop on a microscopic scale. An investigation of the elastic and plastic behaviour of the ferrite lattice in a low-alloy steel showed that the stresses observed by X-ray diffraction exist in a relatively undistorted crystalline material. These stresses were balanced by oppositely directed stresses, either in distorted portions of the crystals adjacent to grain boundaries or in slip bands.

In two-phase alloys the thermal expansion coefficients of the two phases usually differ. Consequently, there is a tendency toward unequal changes in the volume of each phase as the metal cools from the liquid state. The unequal volume changes cause intergranular forces to arise which are known as textural stresses. These stresses are to be distinguished

from the other kind of internal stresses occurring in metals known as body stresses. In Bureau experiments it was possible to measure these textural stresses by X-ray diffraction. Results indicated that a completely stress-free condition cannot be obtained in metals that have more than one phase. Textural stresses must, therefore, be considered in investigations to determine the causes of corrosion, metal fatigue and crack formations in metals used for industrial purposes.

Effects of High and Low Temperatures

The changes that metals undergo at high temperatures are becoming more and more important to the development of rocket machinery and astronautical devices. To a somewhat lesser degree, the effects of very low temperatures on the mechanisms of deformation and fracture of metals are of concern. As new test methods are devised, investigations of high-purity metals and the newer alloys are proceeding under both kinds of environmental conditions. Titanium and its alloys, because of their high strength-to-density ratios and high resistance to corrosion, are promising materials for many cryogenic applications and for certain aircraft and missile components. Since 1949 the Bureau has been studying the mechanical and thermal properties of this comparatively new metal, as a part of its comprehensive programme on the deformation of metals. In early studies for the Army Ordnance Corps, the effects of temperature were correlated with the tensile and impact properties and the true-stress true-strain relations for annealed commercially pure titanium.

It is necessary to know how titanium and its alloys react at low temperatures under both uni-axial tensions in order to understand their rheological behaviour. Several investigations were therefore conducted at temperatures down to −196 deg. Cent. to evaluate the combined influence of prior strain-temperature history and notch geometry on the tensile behaviour of commercially pure titanium and a titanium alloy containing aluminium and manganese. Notch geometry is significant because brittle failures at low temperatures are often associated with the presence of a notch, either as a design feature or as a defect. Measurements of strength and ductility characteristics disclosed that strength indices, such as resistance to flow, notch strength, true stress at maximum load and fracture stress, are generally increased and tensile ductility is decreased by increasing the notch depth or by lowering the test temperature. An analysis of the data indicates that these metals are very notch-sensitive, particularly at low temperatures. The decrease in ductility with increase in depth and sharpness of notch is attributed not only to the initial stress concentration and accompanying severe strain hardening of the metal at the root of the notch, but also to the tri-axial stress system induced by the notch. In general, the embrittling effect associated with the stress concentration was somewhat greater than that caused by the tri-axiality of the stress system. The results emphasise the importance of taking special care to eliminate notches. If they are unavoidable, their embrittling effect should be minimised by designing notches with the largest possible root radius.

It is fairly well accepted that the rate-determining factor during creep of metals is the motion of defects through the crystal lattice by thermal activation under applied stress. However, of the numerous equations proposed to describe this behaviour, none has been found completely satisfactory. To provide basic information that will assist in forming a theory to explain the structural changes that occur during creep, the Bureau has been conducting a long-range programme. In the most recent study, tests were made at temperatures up to 1200 deg. Fah. The influence of stress, strain rate and prior strain history on the mechanism of creep and on the flow and fracture characteristics of high-purity nickel and copper and their alloys was determined. The results conform closely to the concept of generation and exhaustion of lattice defects during the first stage of creep, as well as to the parabolic strain-time law over limited ranges of stress and strain during the second stage. It was found that the resistance to creep is materially increased by alloying the component metals and also by cold-drawing, provided the creep temperature is below the recrystallisation temperature range. The increase in creep resistance by cold-drawing is accompanied by a corresponding decrease in ductility, which is also affected by temperature and strain rate.

Among the studies under way is one using electron microscopy and diffraction to determine the mechanism of hardening of the precipitation-hardening stainless steels, and to establish the relationships between heat-treating variables and the microstructure of metals. These techniques are also being used to investigate the mechanism and kinetics of phase transformations and the structure of metal oxide films.

Stress-rupture testing machines for the study of creep behaviour of metals are shown in Fig. 4.

Mechanical Failure of Metals

For many years the Bureau has examined metal parts that have failed in service to obtain evidence bearing on the causes of failure. These examinations have been undertaken for other Government agencies such as the Ship Structure Committee of the National Research Council, the Civil Aeronautics Board and the Defence Department. From 1942 to 1953 an extensive study was made of steel plates from more than 100 merchant vessels that had fractured while in use. The results of this work showed that the performance of a steel in service can be correlated with the mechanical properties as measured in the laboratory. The information thus derived has provided much of the basis for the current specifications for ship plate.

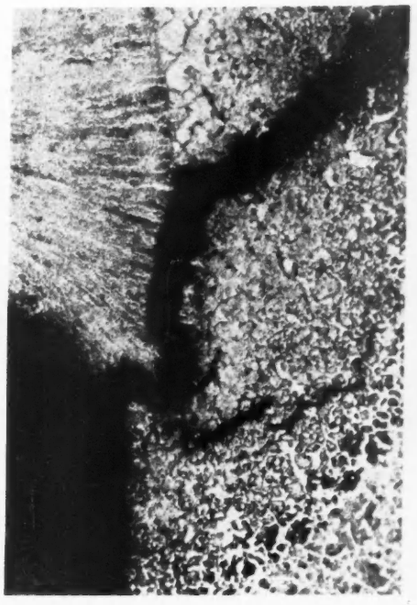


Fig. 5—Section of steel bar showing a brittle weld crack due to cold weather dimensional changes

The accompanying illustration (Fig. 5) shows a section of a steel bar from one of the locks on the St. Lawrence Seaway, showing origin of a fracture. This bar is one of two holding the lock gate in position and cracked because of a stress that developed from dimensional changes during cold weather. N.B.S. studies showed

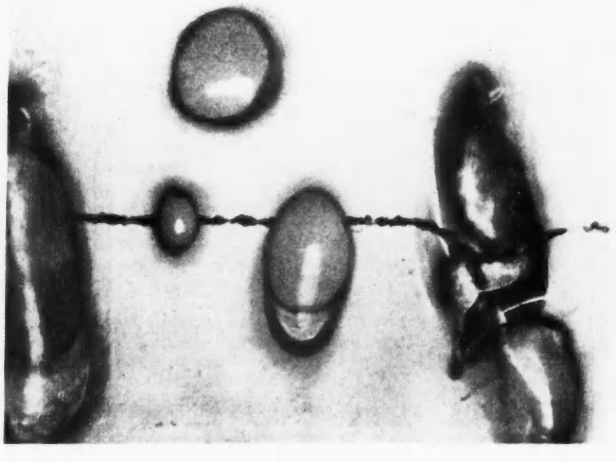


Fig. 3—Gas bubbles produced by repeated stressing on the surface of a fatigue test aluminium specimen

Fig. 4—Stress-rupture testing machines for determining creep behaviour of metals

THE AMERICAN SCENE *(Continued)*

that the steel at the most highly stressed point had been embrittled by the heating effect of a heavy weld. Brittle steel adjacent to the toe of the weld (upper right) is easily distinguished from the normal structure of the metal (lower left).

Investigations for the Civil Aeronautics Board and defence agencies have often had a bearing on decisions regarding the safety of transport aircraft, particularly with regard to correcting conditions that have led to accidents. Laboratory work includes examination of the failed parts by visual, microscopic and metallographic methods, as well as mechanical and chemical tests. Data have been compiled on the circumstances of the failure, together with factors indicating errors in design, in material selection and in fabrication.

Gauge Block Stability

For a number of industrial processes, such as the making of machine tools, ball bearings and missile guidance mechanisms, test gauges for dimensional control must be very precise, and the gauge blocks used in checking the accuracy of these gauges must be even more accurate. At present the Bureau regularly calibrates master gauge blocks to an accuracy of 1 part in 1,000,000, i.e. to the nearest millionth of an inch for inch-long blocks, and a goal has been set to increase this accuracy by a factor of ten. As part of this programme, which is partially supported by several industrial firms, extremely stable materials are being sought for gauge block construction, so that measured lengths will not change appreciably with time. From recent experiments, nitrided A.I.S.I. Type 410 stainless steel appears to be a promising material for ultra-precise gauge blocks. The specimens were found to be corrosion-resistant in atmospheric conditions. Moreover, the gauging surfaces are extremely hard and wear-resistant and can be finished to a high degree of smoothness, flatness and parallelism. Measurements thus far indicate that these specimens have the required dimensional stability. However, evaluations will continue for an extended period, since previous observations of commercial blocks have shown that the results of measurement over a year or two are not necessarily indicative of future behaviour.

Looking ahead to the metallurgical requirements of a space age, the Bureau expects to place increasing emphasis on the study of all aspects of atomic structure that influence the behaviour of metals in service. At present, techniques are being developed to obtain basic data that may point the way to new uses for metals. Ultimately this work may lead to new alloys that will withstand the most rigorous of environmental and physical conditions.

Fast Electronic Memory for Computer Application

COMPUTER technology has been significantly advanced by the recent development of a new, accurate and fast electronic memory. Hair-thin wires wrapped with magnetic metal tape and small bar magnets are the basic elements of a permanent electronic memory which is comparatively inexpensive, is easy to produce and will help to speed up computer developments. The memory will supply bits of information at speeds in millionths of a second to a computer.

The permanent-magnet memory is the result of two technical achievements : the conception of a memory based on the inhibiting action of a permanent magnet on the magnetic characteristics of a " Twistor " formulated by the Bell Telephone Laboratories ; and the development, in fourteen months, of mass production facilities for memory units by the Western Electric Company. The manufacture of the memory modules in quantity and at the levels of precision demanded by the small dimensions and close registration of some of its components required close co-operation of technical personnel in both concerns. The development, design and pilot production phases have now yielded a unit which can be efficiently manufactured by automatic techniques. Thus, programme memory units for computer systems are available which combine high-speed operation and reliability that was formerly unobtainable.

The memory module is built up of arrays of very small permanent bar magnets situated on plastic cards which are superimposed on a " Twistor "-conductor grid sensing element. The bar magnets are formed by first bonding a 0·001in thick sheet of Vicalloy 1, a magnetic material, to a plastic card. The card is then subjected to a high-precision photo-etching process to eliminate all the magnetic material except the small bars left at specifically desired locations. The tolerances required for this photo-etching process are far narrower than those needed in standard photo-etching work.

The sensing element for these magnets is an underlying grid of horizontal and vertical conductors. The wires running in one direction are magnetic and are called " Twistors," while those in the perpendicular direction are current conductors. " Twistors " are prepared by putting a spiral wrapping of " Molypermalloy " magnetic tape around a copper carrier wire. This wrapping produces a spiral magnetic path around the conductor when a current is passed along the tape and the carrier wire. A number of these magnetic wires are embedded in a strip of " Mylar " film, each with a plain copper wire alongside it to act as a return current carrier. The other co-ordinate of the grid is made up of strips of copper foil 0·060in wide, also embedded in a " Mylar " film. This conductor-bearing film is folded over the " Twistor " strip in such a way that one complete loop is formed ; each loop of copper strip provides a single turn solenoid at right angles to the " Twistors." For access to the memory the open end of the solenoid, or " word coil," is connected to a biassed ferrite core switch or transformer. Because of the square-hysteresis-loop characteristics of this core, it also provides a selection scheme for picking a particular " word coil " out of a matrix of such coils. Neither the ferrite core switch nor the " Twistor "-conductor grid stores information in itself ; they are used only for access to the permanent-magnet memory.

The " Twistor "-conductor grid is used to sense the presence or absence of a field from a permanent magnet. The field inhibits the action of an electrical pulse through a " word coil " on the magnetic properties of the " Twistor " itself. If there is no magnet at a given intersection, a corresponding pulse is generated in the " Twistor " and read out. If a magnet is present, its field prevents the production of the " Twistor " pulse ; and no signal is read out. The signal from the " Twistor " is about 6mV at an impedance level of 10 ohms and is about 1 microsecond long. The computer interprets this signal or lack of signal to indicate a specific command and acts on it to do its computation. By inserting a new card with a different arrangement of magnets, the memory can be easily and reliably changed to a new programme when conditions require. Accuracy of registration in the programme cards is ensured by the use of guide pins, and the entire card is held in close proximity to the " Twistor " grid by springs. The separation of the magnets from the sensing wires is only a few thousandths of an inch. There are no wired connections between co-ordinate wires of the access grid or between the grid and the permanent-magnet memory—their interaction results from proximity alone.

The first step in the manufacture of the " Twistor "-conductor grid is the preparation of the magnetic tape used in wrapping the copper carrier wire to form the " Twistor." " Molypermalloy " wire is first drawn to a diameter of approximately 0·001in, then roll-flattened to a tape 0·0035in wide by 0·0003in thick. A specially designed test set continuously checks the magnetic quality of the wire, allowing identification of that part of the product which could

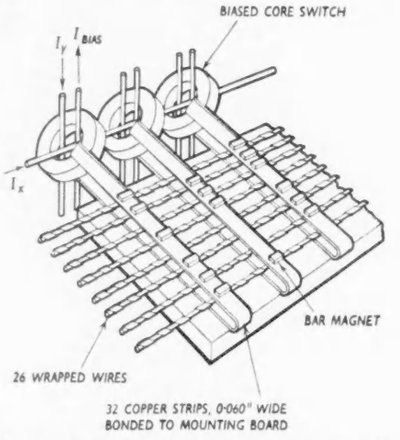


Diagram of " Twistor "-magnet memory frame, with three core switches and eight intersecting " Twistors "

cause faulty operation of the memory. The wrapping process required a development programme of its own. A machine had to be designed which took into account the low strength of the materials involved, yet would wrap the tape about the 0·003in diameter carrier wire quickly and uniformly. The high uniformity is necessary to minimise variation in the magnetic characteristics of the final assembly. An output of 300ft of " Twistor " per hour is possible with the machines now in use. With a 45 deg. helix, this output requires 1140 turns of tape per foot of carrier wire or a speed of 5700 r.p.m. for the wrapping head.

Twenty-six pairs of " Twistor "-return wires are then laminated between sheets of " Mylar " tape. These wire pairs are positioned on 0·100in centres across the width of the tape ; the separation between a " Twistor " and its associated return wire is 0·020in. A memory module is built by interweaving the " Twistor " tape, the copper " word coils " and the plastic magnet cards. An array of very small transformers is made, one connected to each " word coil " of the module. A registration mechanism ensures that the magnets on any programme card are aligned over the proper bit position. The unit is assembled into a compact, mechanically rigged, reliable memory package. A special test set, which is essentially a computer in itself, was required because of the complexity of the module and the variety of conditions under which the memory module might be required to operate.

The " Twistor " got its name from early work by A. H. Bobeck, of the Bell Laboratories, who showed that a wire with a twisted magnetisation could be switched by either current flowing down the wire or by current flowing down another wire perpendicular to it. If such wires were then woven into a grid with plain copper wires, the intersections could be used to store bits of information in a temporary computer memory.

BRITISH PATENT SPECIFICATIONS

The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each

WATER PURIFICATION

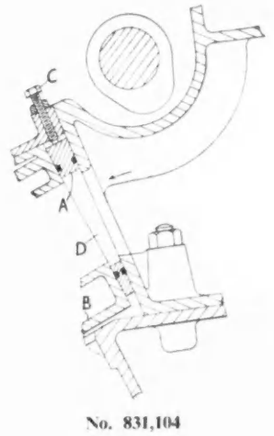
830,964. January 13, 1956.—Water Purification, John Thompson-Kennicott, Ltd., Wolverhampton, England. (*Inventor: George Travis Davison.*)

An object of this invention is to provide a method of water purification which effectively reduces the quantity of organic matter both in solution and in colloidal suspension. The method comprises the adding of potassium permanganate to raw water in a quantity insufficient to effect complete oxidation of organic matter, so that oxides of manganese and or their hydrates are precipitated. The precipitate is of a colloidal nature and is impossible to remove by normal filtration through sand. It has been found possible to filter out the fine particles of the precipitate through a porous mineral of granular form which has been successively treated with solutions of manganese sulphate and potassium permanganate so as to deposit manganese dioxide. It has also been found that the bed of ion exchange resins acts as a filter for the removal of the precipitate in certain cases. To a certain extent the hydroxides of manganese react with acid of the resin and form a manganese salt of the resin, with the liberation of oxygen. By backwashing the ion exchange resins and subsequent regeneration, the manganese where present in the combined or free state can be effectively removed. The time required for the reaction between the permanganate and the organic material present in the raw water may be very small and it may be allowed to take place in an external chemical reaction tank or in the space available above the bed of exchange resin. To ensure that the water after filtration does not still contain potassium permanganate which has not been reduced, less potassium permanganate is added to the raw water than is required for complete oxidation of the organic matter. It is preferred to add a catalyst, for example, copper, to the raw water being treated in addition to potassium permanganate.—*March* 23, 1960.

INTERNAL COMBUSTION ENGINES

831,104. July 16, 1958.—Engines and Joint-Making Means, Edward Moller, Cuthbert Coulson Pounder and Sir Frederick Ernest Rebbeck, all of Harland and Wolff, Ltd., Queen's Island, Belfast, Northern Ireland.

This invention relates to internal combustion engines and to joint-making means where it is not possible to use conventional gaskets or joint flanges and where it is necessary to provide a fluid-tight seal about a fluid connection between two components,



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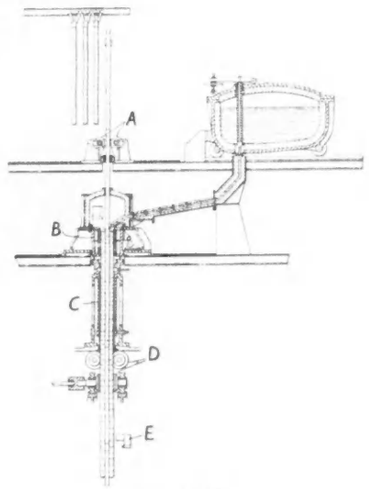
such as a gas-tight seal for an air inlet supply to a cylinder head or a liquid-tight seal for water cooling conduits for a cylinder or cylinder head. The drawing illustrates an example according to the invention in which a wedge-shaped packing member *A* is inserted between a side face of a cylinder head *B* and the opposed face of an air inlet manifold casing. The packing member has grooves with sealing strips which are pressed against the opposed faces of the components by jacking screws *C* screwed through a thrust member. The packing has a central air inlet aperture *D* which is adapted to register with the apertures in the faces of the cylinder head and manifold casing.—*March* 23, 1960.

TUBE MAKING PLANT

831,494. November 7, 1957.—Continuous Casting of Metal Tubes, The Wellman Smith Owen Engineering Corporation, Ltd., Parnell House, 25, Wilton Road, London, S.W.1. (*Inventor: Cyril Brooks.*)

According to the invention a method of producing a metal tube comprises progressively introducing a core into one end of an open-ended mould, feeding molten metal to that end of the mould around the core member, and progressively removing the metal and the core through the other end of the mould. In use of the apparatus shown, the core member, comprising abutting succeeding sections, is fed by the upper pinch rolls *A* through the mould. Molten metal is delivered by pipe from the tundish to the open top of the mould to surround the core. At the bottom of the mould the metal becomes partially



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solidified and passes out of the open lower end of the mould with the core member. As the cast tube passes downwards it is still further cooled by water passed through the depending tube *C*. Below the framework the lower pinch rolls *D* engage the cast tube, which has now solidified sufficiently, and help to draw it through the mould together with the core. As the cast tube is continuously formed and progresses downwardly past the lower pinch rolls, it is cut into lengths by the apparatus *E* which operates at or about the junction of two sections of the core.—*March* 30, 1960.

METALLURGY

830,775. October 24, 1958.—Dies and Alloy Therefor, General Electric Company, 1, River Road, Schenectady 5, State of New York, United States of America.

This invention relates particularly to dies and alloys for use in both hot and cold forming operations. Briefly, materially increased die life can be achieved for dies when they are made from an alloy containing, by weight, 0·5–0·6 per cent carbon, 1·5–2·5 per cent manganese, 1·25–2·5 per cent silicon, 3–4 per cent chromium, 0·75–1·5 per cent tungsten, 1–2 per cent nickel, 0·75–1·5 per cent vanadium, with the balance iron. The alloys are characterised by improved high impact strength, wear resistance and hot hardness in addition to excellent resistance to thermal checking. These alloys, which are air hardening and have a minimum hardness of 25 Rockwell "C," can be cast into an ingot from about 2800 deg. Fah. The cast ingot may then be formed, as by forging, in a temperature range of 2050–2100 deg. Fah. After forming, the alloy is annealed by first holding it for one hour at about 1475 deg. Fah. to form austenite in the alloy, then the die stock is cooled to about 1275 deg. Fah. and held at that temperature for about four hours before being cooled to room temperature. It is then reheated and maintained at about 1275 deg. Fah. for about six hours before cooling to room temperature.—*March* 23, 1960.

FOUNDRY EQUIPMENT

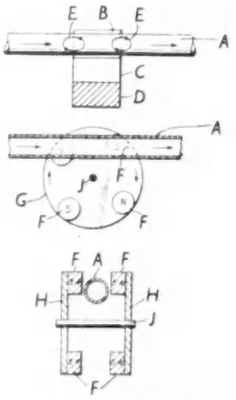
831,162. June 27, 1957.—Separating Agent for Foundry Moulds and Cores, British Petroleum Company, Ltd., Britannic House, Finsbury Circus, London, E.C.2.

According to this invention, a separating oil is prepared by converting a refined mineral oil fraction which burns without leaving a residue into a stable water-in-oil emulsion and incorporating into the oil-in-water emulsion an aqueous solution of inorganic salts to produce a composition containing: 51·5 per cent by weight of water; 40 per cent by weight of the oil fraction; 4 per cent by weight of sodium chloride; 2 per cent by weight of ammonium sulphate; 2 per cent by weight of aluminium sulphate; 0·5 per cent by weight of non-ionic emulsifier. The refined mineral oil fraction should preferably be one in the boiling range 250–350 deg. Cent. at 20 Torr, and the formation of the emulsion should preferably be effected by means of a chemically-inactive water-in-oil emulsifier (or emulsifiers) which burns without leaving a residue, such as an ethylene oxide polymer.—*March* 23, 1960.

INSTRUMENTATION

831,226. May 1, 1957.—Electromagnetic Flowmeters, United Kingdom Atomic Energy Authority, London. (*Inventor: John Arthur Shercliff.*)

The upper drawing shows a known type of flowmeter in which a conducting fluid *A* in tube *B* flows past the poles of permanent magnet *C* with yoke *D*. The motion of the fluid under the transverse magnetic field produces a potential difference between two electrodes (not shown) and this p.d. is used as an indication of flow rate. Circulating currents *E* distort the field, producing a force proportional to flow rate in the downstream direction. In the present invention this force acts on several magnets *F* (lower drawings) disposed round the periphery of a rotatable member *G*. There are no electrodes, and the speed of rotation of the member is a measure of the flow-rate. As shown in the bottom drawing, member *G*



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comprises two cheeks *H* made of steel carried on a brass axle *J*. As member *G* revolves, the fields between successive pairs of facing poles are cut by the tube, which is preferably of insulating material. Conducting material, such as stainless steel, may be used, however, providing the conductivity of the liquid is sufficiently high, as with liquid sodium, so that the magnetic forces are larger and the walls divert less current from the liquid.—*March* 23, 1960.

RUST PREVENTIVES

831,046. January 23, 1957.—Emulsifiable Rust Preventive Concentrate, Esso Research and Engineering Company, Elizabeth, New Jersey, United States of America.

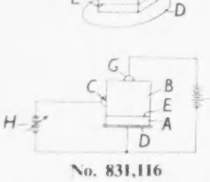
The emulsifiable rust-preventive composition described comprises a mixture of from 72 to 95 per cent of a base composition containing from 10 to 25 per cent of a mineral oil having a viscosity from 60 to 3000 Saybolt Universal seconds at 100 deg. Fah., from 10 to 25 per cent of an alkali metal salt of a sulphonic acid having a molecular weight from

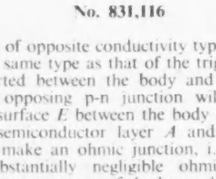
250 to 800 and from 22 to 50 per cent of neutral degras ; together with from 1 to 10 per cent of a coupling agent comprising a glycol ether or polyglycol ether having from 5 to 15 carbon atoms in the molecule and from 1 to 18 per cent of a balancing agent comprising a polyhydroxy amine and water having a water-to-amine ratio from 4 1 to 14 1 or a polyalkylene oxide derivative of a fatty amine and water in the proportion 1 to 14 parts of water per part of amine derivative, all these percentages being based on the total product.—*March* 23, 1960.

ELECTRONICS

831,116. February 7, 1955.—SEMICONDUCTOR DEVICES, The British Thomson-Houston Company, Ltd., Crown House, Aldwych, London, W.C.2. (*Inventor : Edgar Frederick Dawson.*)

This invention relates to semiconductor devices and more particularly to those known as double base diodes. The term "double base diode" refers to a device comprising a body of semiconductor material having only three electrodes, namely, two base electrodes spaced apart and a triggering electrode forming a p-n junction with the semiconductor body at a point intermediate the base electrodes. An arrangement of the invention is shown in the upper drawing, where a layer of semiconductor material





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A which is of opposite conductivity type to the body *B*, but the same type as that of the trigger electrode *C*, is inserted between the body and the base *D*. Thus, an opposing p-n junction will be formed along the surface *E* between the body and the layer *A*. The semiconductor layer *A* and the base *D* preferably make an ohmic junction, i.e. a junction having substantially negligible ohmic resistance. The circuit arrangement of the lower drawing shows a typical circuit embodying the invention in which a bias voltage *F* is applied between base electrodes *G* and *D* whilst a variable triggering voltage *H* is applied between the trigger electrode and the base *D*, and in which the body is of *n* type material. So long as the voltage applied to the electrode *C* is such that it is less positive than the potential in the adjacent semiconductor body *B* due to *F* then no current will flow through the p-n junction between the trigger electrode and the body. If, however, *H* is progressively increased until the potential applied to the trigger is substantially the same as that in the adjacent part of the semiconductor the p-n junction between the electrode *C* and the body will suddenly become highly conducting, so that current will flow through the external circuit and through the body between the trigger electrode and the base *D*. In arrangements embodying the invention, however, the flow of base current before triggering occurs will be opposed by the p-n junction formed at the surface *E*. An alternative construction in which the semiconductor body is in the form of a circular disc is also described.—*March* 23, 1960.

PRESSES

828,645. June 26, 1957.—FRICTION-DRIVEN SCREW PRESSES, Etablissements Grimar, 27 to 35, rue Bréguet, Paris, France.

The invention provides a friction screw press in which the flywheel is driven alternately in either direction by two drums with an axial length at least equal to the length of travel of the flywheel and rotatable in opposite directions. The driving drums are mounted on two supports, pivoting in opposite directions and connected by the rod of a double-acting piston. The supports are spring loaded to a position, in which both drums are out of contact with the flywheel. Conveniently the drums are driven by separate motors which eliminates the use of transmission gears, and enables the drums to be rotated at a speed much higher than in other systems. The system controlling the supply of pressure fluid to the double-acting cylinder performing the alternate application of the drums to the flywheel, incorporates an auxiliary contact breaker. The height of this contact breaker is adjustable with reference to the travel of a control cam fixed on the crosshead in such a manner that the drum producing the downward motion can be uncoupled from the flywheel before the end of the stroke at a variable point in the stroke, or remain coupled for the whole stroke. This arrangement enables, in the case of a stamping press, the force of the blow of the machine to be varied at will.—*February* 24, 1960.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ANTIQUARIAN HOROLOGICAL SOCIETY

Tues., May 3.—Science Museum, South Kensington, London, S.W.7, Annual General Meeting, 7 p.m.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, April 29.—COVENTRY AND DISTRICT BRANCH : Visit to Coventry Telephone Exchange, 7.30 p.m.

Mon., May 2.—BOLTON BRANCH : Railway Hotel, Trinity Street, Bolton, "Modern Installation Economics," K. Briars, 7.45 p.m. ★ CENTRAL LONDON BRANCH : White Hall Hotel, Bloomsbury Square, London, W.C.1, "Gaseous Isotope Light Sources," H. L. Privett, 7.15 p.m. ★ ESSEX BRANCH : Angel Hotel, Ilford, Essex, "Ball and Roller Bearings," T. S. Nisbet, 8 p.m. ★ LEEDS BRANCH : Great Northern Hotel, Leeds, Films Evening, 7.30 p.m. ★ SHEFFIELD BRANCH : Royal Victoria Hotel, Sheffield, Open Night, 7.30 p.m.

Wed., May 4.—HALIFAX BRANCH : Crown Hotel, Horton Street, Halifax, "Lesser-known Regulations in the 13th Edition of the I.E.E. Regulations," E. Smith, 7.45 p.m. ★ PRESTON BRANCH : R.A.F.A. Club, East View, Preston, "Lighting Techniques in Shops and Stores," J. O'Reilly, 7.30 p.m.

Fri., May 6.—LIVERPOOL AND DISTRICT BRANCH : Industrial Development Centre, M.A.N.W.E.B., Paradise Street, Liverpool, 1, Films and colour film of the 1959 Electrical Engineers (A.S.E.E.) Exhibition, 7.30 p.m. ★ STOKE AND CREWE BRANCH : Grand Hotel, Hanley, "Fire Alarms," 7.30 p.m.

BRITISH COMPUTER SOCIETY

Wed., May 11.—BIRMINGHAM BRANCH : Large Theatre, Electrical Engineering Department, The University, Edgbaston, Birmingham, Annual General Meetings of the Branch and of the Midland Region, 6.30 p.m.

BRITISH INSTITUTE OF MANAGEMENT

To-day and Sat., April 29 *and* 30.—Gleneagles, Scotland, 1960 Scottish Conference on "Management Problems in an Expanding Economy."

BRITISH INSTITUTION OF RADIO ENGINEERS

To-day, April 29.—SOUTH MIDLANDS SECTION : North Gloucestershire Technical College, Cheltenham, "The Application of Semiconductor Devices in Power Supplies," D. D. Jones, and Annual General Meeting, 7 p.m.

Wed., May 4.—COMPUTER GROUP : London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Computer Controlled Television Displays for Flight Simulators," J. N. Nash, 6.30 p.m. ★ LIVERPOOL BRANCH : University Club, 2, Mount Pleasant, Liverpool, Annual General Meeting, 7 p.m.

Wed., May 11.—RADAR GROUP : London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Radio Guidance in the Automatic Landing of Aircraft," J. S. Shasler, 6.30 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Wed., May 11.—SOUTHERN REGION : Great Western Hotel, Station Road, Reading, Discussion on "The Ability of Mechanical Stokers to Comply with Section 1 of the Clean Air Act," 10.30 a.m.

ENGINEERING INDUSTRIES ASSOCIATION

Thurs. to Sat., May 12 *to* 14.—2ND NATIONAL CONFERENCE : Royal Hotel, Scarborough, "The Development of Your Business," 9.30 a.m.

ILLUMINATING ENGINEERING SOCIETY

Thurs., May 5.—NOTTINGHAM CENTRE : Electricity Centre, Carrington Street, Nottingham, Annual General Meeting, 6 p.m.

INSTITUTE OF FUEL

Fri., May 6.—SOUTH WALES SECTION : South Wales Institute of Engineers, Park Place, Cardiff, Annual General Meeting, 6 p.m.

INSTITUTE OF PETROLEUM

Wed., May 4.—Lecture Theatre, 61, New Cavendish Street, London, W.1, "The Stabilization of Crude Oil," F. C. Thomas, 5.30 p.m.

INSTITUTE OF PHYSICS

Mon. to Wed., May 2 to 4.—NON-DESTRUCTIVE TESTING GROUP : Lecture Theatre, Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, Joint Conference with the Société Française de Metallurgie, "Physical and Structural Aspects of Non-destructive Testing of Metals," Mon., 1 45 p.m. ; Tues. and Wed., 9 a.m.

INSTITUTE OF REFRIGERATION

Thurs., May 5.—Institute of Marine Engineers, Memorial Building, 76, Mark Lane, London, E.C.3, Joint Meeting with the Institution of Heating and Ventilating Engineers, "The Demand for Cooling in the Modern Passenger Liner," A. J. Barnard and S. J. Jones, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Fri., May 13.—SOUTH WALES CENTRE : South Wales Institute of Engineers, Park Place, Cardiff, Films, "Cummins Diesels," 7.15 p.m.

INSTITUTE OF WELDING

Mon. to Wed., May 9 to 11.—Spring Meeting at Droitwich.

INSTITUTION OF CHEMICAL ENGINEERS

Wed. to Fri., May 4 *to* 6.—24TH MEETING OF THE EUROPEAN FEDERATION OF CHEMICAL ENGINEERING : The Dome, Brighton, International Symposium on "Distillation."

INSTITUTION OF CIVIL ENGINEERS

Tues., May 3.—Great George Street, Westminster, London, S.W.1, Symposium on "London/Birmingham Motorway," 2.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, April 29.—SOUTH MIDLAND EDUCATION DISCUSSION CIRCLE : College of Technology, Gosta Green, Birmingham, Discussion on "The Generalized Analysis of Electrical Machines," opened by J. G. Henderson, 6 p.m. ★ NORTH EASTERN GRADUATE AND STUDENT SECTION : Grey Hall, King's College, Newcastle upon Tyne, 1, Annual General Meeting and Film Show, 6.30 p.m.

Sat., April 30.—LONDON GRADUATE AND STUDENT SECTION : Visit to Bankside Power Station, London, S.E.1, 10.30 a.m.

Mon., May 2.—ELECTRONICS AND COMMUNICATIONS SECTION : Savoy Place, London, W.C.2, "Planning and Installation of the Sound Broadcasting Headquarters for the B.B.C.'s Oversea and European Services," F. Axon and O. H. Barron, 5.30 p.m.

★ LONDON GRADUATE AND STUDENT SECTION : Assembly Hall, 3 (Tels.) Training Bn., R.E.M.E., Arborfield, Berks, "Silicon Transistors—their Manufacture and Fields of Application," J. T. Kendall, 7 p.m. ★ EAST ANGLIAN SUB-CENTRE : Cavendish Laboratory, Cambridge, Annual General Meeting, and "Fundamental Particles," O. R. Frisch, 6.30 p.m. ★ SOUTH MIDLAND CENTRE : James Watt Memorial Institute, Birmingham, "Radio Aspects of the International Geophysical Year," R. L. Smith-Rose, 6.30 p.m.

Tues., May 3.—MEASUREMENT AND CONTROL SECTION : Savoy Place, London, W.C.2, Discussion on "Teaching and Learning Machines," opened by C. E. G. Bailey, 5.30 p.m. ★ NORTH MIDLAND CENTRE : Leeds and County Conservative Club, South Parade, Leeds, 1, Annual General Meeting, 6.30 p.m. ★ NORTH-WESTERN CENTRE : Engineers' Club, Manchester, Annual General Meeting, and Informal Discussion, 6.15 p.m. ★ NORTHERN IRELAND CENTRE : David Keir Building, Queen's University, Stranmillis Road, Belfast, Annual General Meeting, 6.30 p.m.

Wed., May 4.—NORTH LANCASHIRE SUB-CENTRE : N.W.E.B. Demonstration Theatre, Friargate, Preston, Annual General Meeting, and "Storage and Manipulation of Information in the Brain," R. L. Beurle, 7.15 p.m. ★ LONDON GRADUATE AND STUDENT SECTION : Visit to Leo Computers, Ltd., London, W.2, 2.15 p.m.

Thurs., May 5.—UTILIZATION SECTION : Savoy Place, London, W.C.2, "Safety in the Utilization of Electricity," S. J. Emerson, 5.30 p.m. ★ SOUTH-WESTERN SUB-CENTRE : Electric Hall, Torquay, "The Application of Transistors to Line Communication Equipment," H. T. Prior, D. J. R. Chapman and A. A. M. Whitehead, 3 p.m.

Fri., May 6.—MEDICAL ELECTRONICS DISCUSSION GROUP : Savoy Place, London, W.C.2, Discussion on "Methods of Recording Measurements—Digital or Analogue," opened by W. J. Perkins, 6 p.m.

Sat., May 7.—LONDON GRADUATE AND STUDENT SECTION : Visit to National Physical Laboratory, Teddington, 10 a.m.

INSTITUTION OF ENGINEERING DESIGNERS

Wed., May 4.—MIDLANDS BRANCH : Queens Hotel, Birmingham, Annual General Meeting, 7 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, April 29.—COVENTRY GRADUATES' A.D. CENTRE : Visit to Coventry Climax Engines, Ltd., 6 p.m.

Wed., May 4.—JAMES CLAYTON LECTURE : 1, Birdcage Walk, Westminster, London, S.W.1, "The High-Speed Heavy-Duty Diesel Engine : Its Development, Design and Application," Ekbart Schmidt, 6 p.m. ★ WESTERN GRADUATES' SECTION : Technical College, Chippenham, "Bristol Siddeley 3MW Turbo-generator," P. J. McMahon, 7.30 p.m.

Fri., May 6.—WESTERN BRANCH : The Duke of Cornwall Hotel, Millbay Road, Plymouth, Meeting with the Institution of Structural Engineers, "The Jodrell Bank Radio Telescope," H. C. Husband, and Film, "The Inquisitive Giant," 6 p.m.

Sat., May 7.—SOUTHERN BRANCH : Visit to the site of the Proton Synchrotron at the Rutherford High Energy Laboratory, Harwell, 2 p.m. ★ WESTERN BRANCH : Visit to Hinkley Point Nuclear Power Station, Bridgwater, Somerset, 10.30 a.m.

Tues., May 10.—SOUTHERN GRADUATES' SECTION : South Dorset Technical College, Newstead Road, Weymouth, "The Dragon Reactor Experiment," G. E. Lockett, 7.30 p.m.

INSTITUTION OF PLANT ENGINEERS

To-day, April 29.—BIRMINGHAM BRANCH : Imperial Hotel, Temple Street, Birmingham, "Materials Handling—Fork Trucks, &c., Maintenance and Repairs," 7.30 p.m.

Tues., May 3.—LONDON BRANCH : Royal Society of Arts, John Adam Street, Adelphi, Strand, London, W.C.2, "Oil Refinery Utilisation of Heavy Constructional Machinery," A. W. F. Abbott, 7 p.m. ★ PETERBOROUGH BRANCH : White Lion Hotel, Church Street, Peterborough, Members' papers, 7.30 p.m.

Wed., May 4.—SOUTHERN BRANCH : Polygon Hotel, Southampton, "Insulation of Buildings," J. Churton, 7.30 p.m.

Wed. to Fri., May 4 *to* 6.—Grand Hotel, Scarborough, 1960 Annual Conference.

JUNIOR INSTITUTION OF ENGINEERS

To-day, April 29.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "A Journey from Venice to Dubrovnik," G. V. Rickards, 7 p.m.

Wed., May 4.—MIDLAND SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, Visit of the President who will re-deliver his Presidential Address, "The Engineer's Role in Nuclear Power," J. M. Kay, 7 p.m.

Fri., May 6.—ORDINARY MEETING : Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Standardisation of Some Electrical Measuring Instruments," F. W. L. Bosch ; to be read by W. J. Hart, 7 p.m.

NEWCOMEN SOCIETY

Wed., May 4.—Science Museum, South Kensington, London, S.W.7, 4th Dickinson Biennial Memorial Lecture, "Roots in the Past," R. J. Forbes, 5.30 p.m.

PLASTICS INSTITUTE

To-day, April 29.—MIDLANDS SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, 3, "Fibre Resin Preform Moulding," A. Lewin, 6.30 p.m.

Tues., May 3.—LONDON AND DISTRICT SECTION : Wellcome Building, 183-193, Euston Road, London, N.W.1, Annual General Meeting, and a speaker from the Plastics Industry of the U.S.S.R., 6.30 p.m.

REINFORCED CONCRETE ASSOCIATION

To-day, April 29.—WEST OF ENGLAND BRANCH : New School of Engineering, The University, Bristol, "Precasting in Concrete Framed Construction," J. F. Greimig and R. C. Westbrook, 6 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., May 2.—ORDINARY GENERAL MEETING : 12, Great George Street, Westminster, London, S.W.1, "The Redevelopment of Decayed Areas," H. F. Alston, 5.45 p.m.

ROYAL METEOROLOGICAL SOCIETY

Wed., May 4.—SYMONS MEMORIAL LECTURE : 49, Cromwell Road, London, S.W.7, "The General Circulation of the Atmosphere," Ragnor Fjortoft, 5 p.m.

SOCIETY OF ENGINEERS

Mon., May 2.—Geological Society, Burlington House, Piccadilly, London, W.1, "Problems in the Launching of 'Black Knight,'" C. E. Tharratt, 5.30 p.m.

Advanced Engineering Courses

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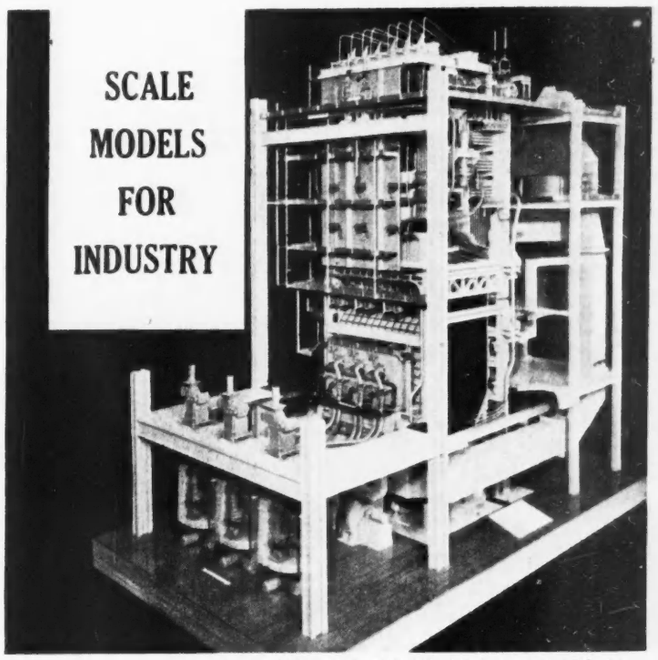

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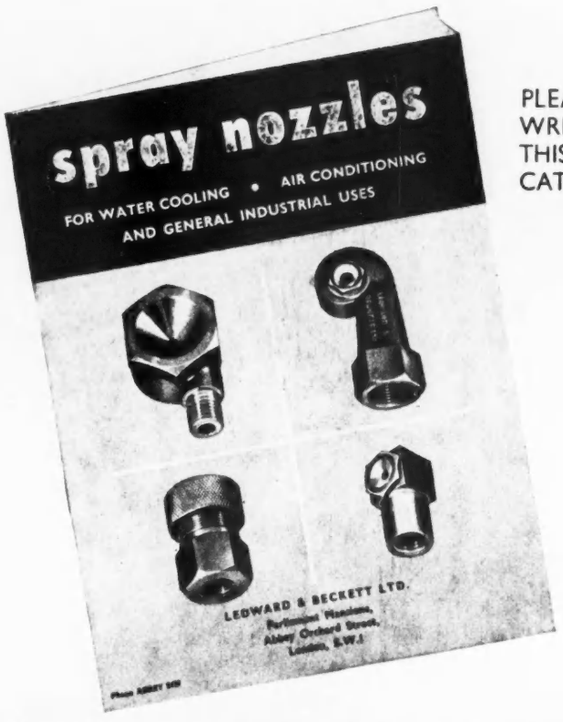

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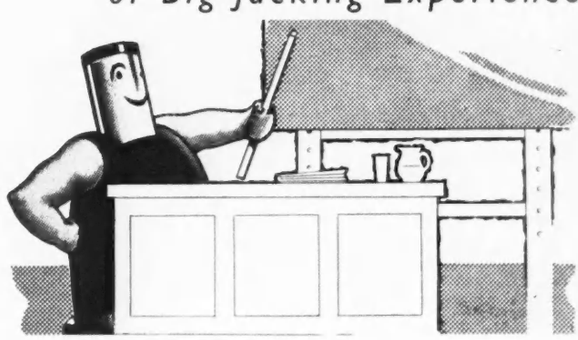

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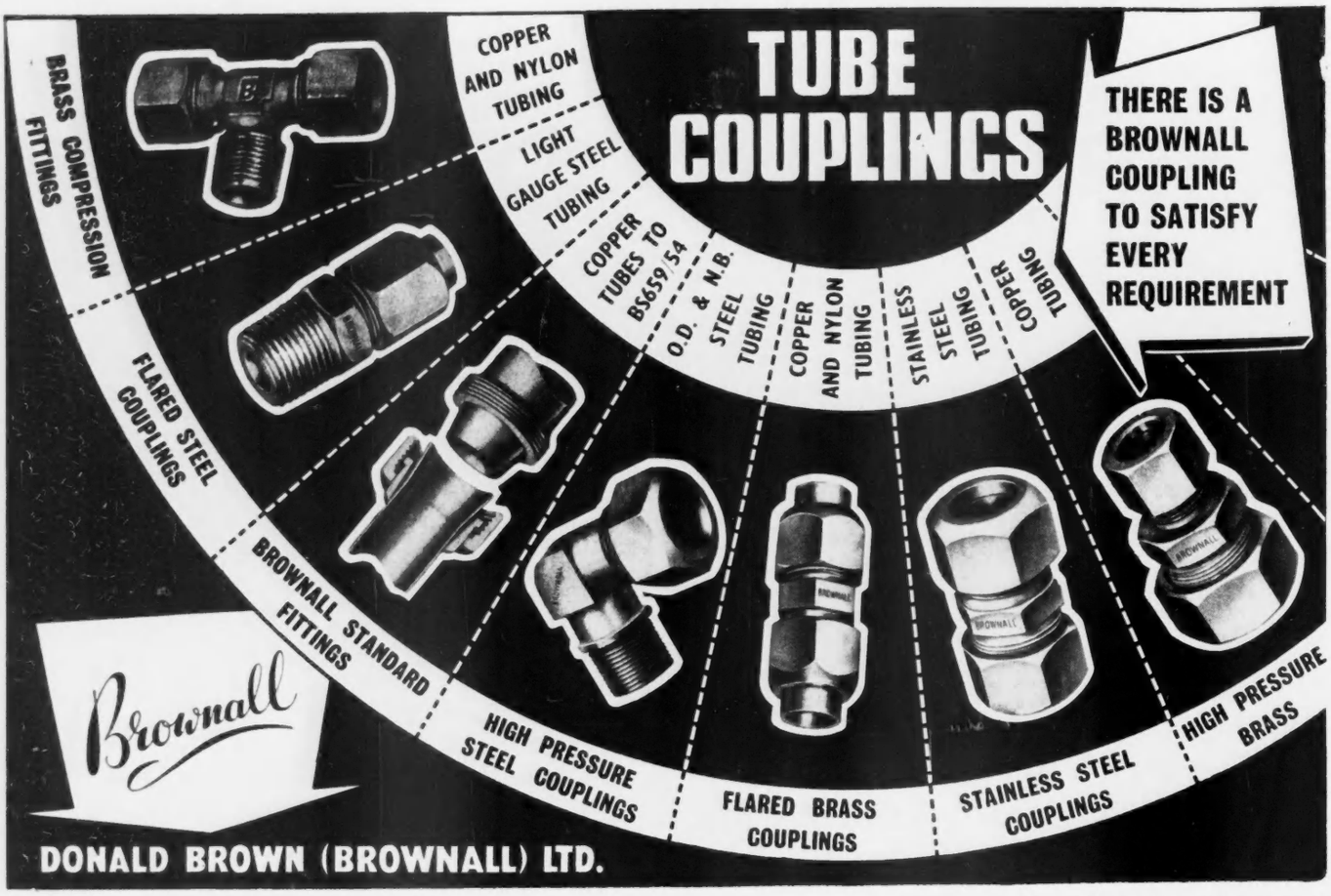

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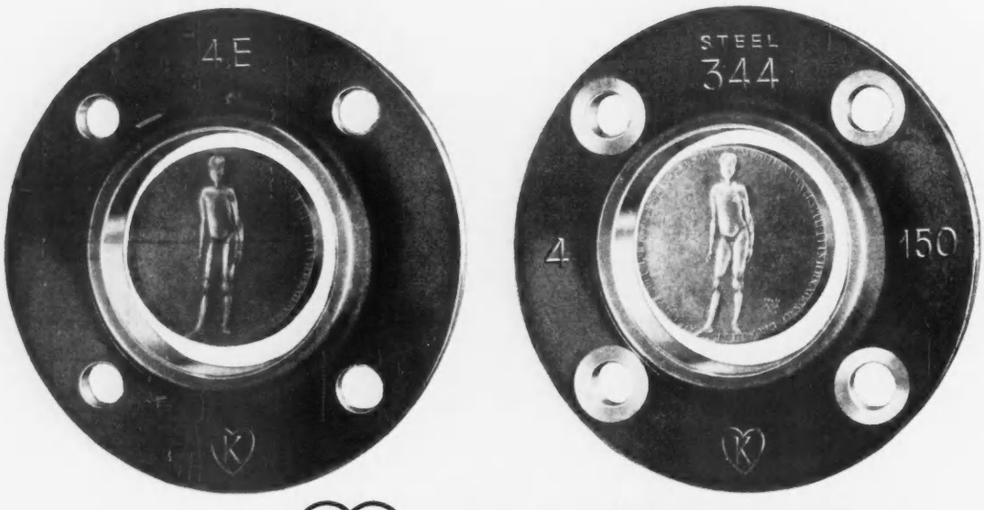

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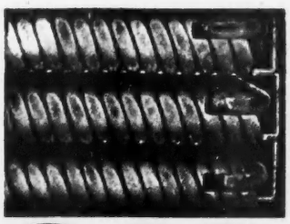

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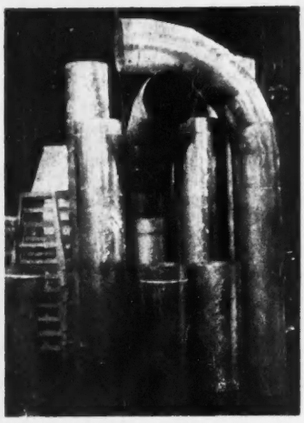

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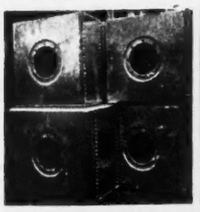

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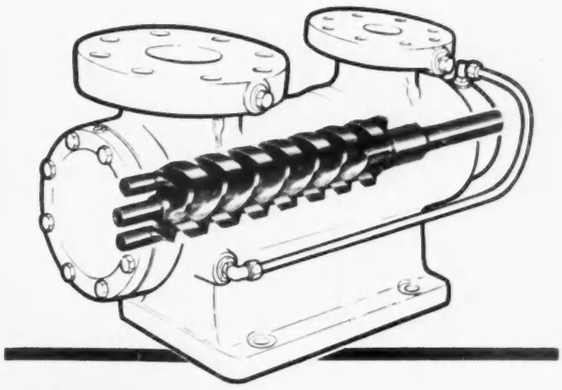

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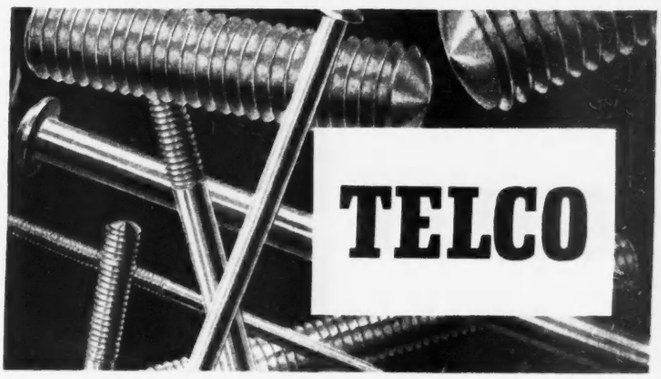

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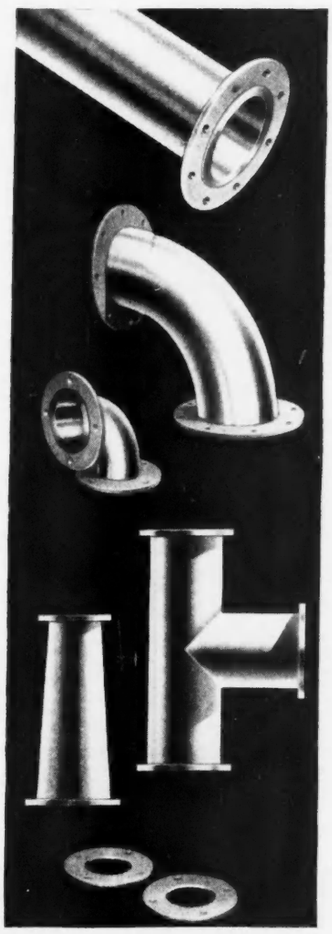

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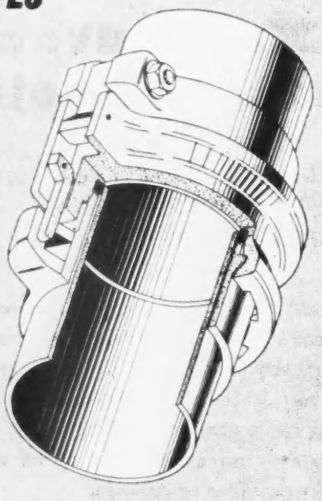

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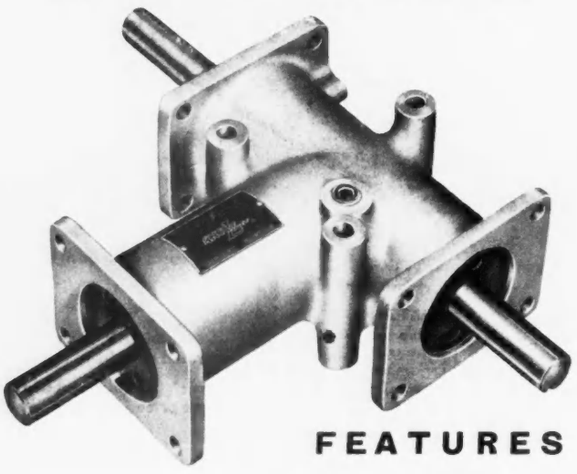

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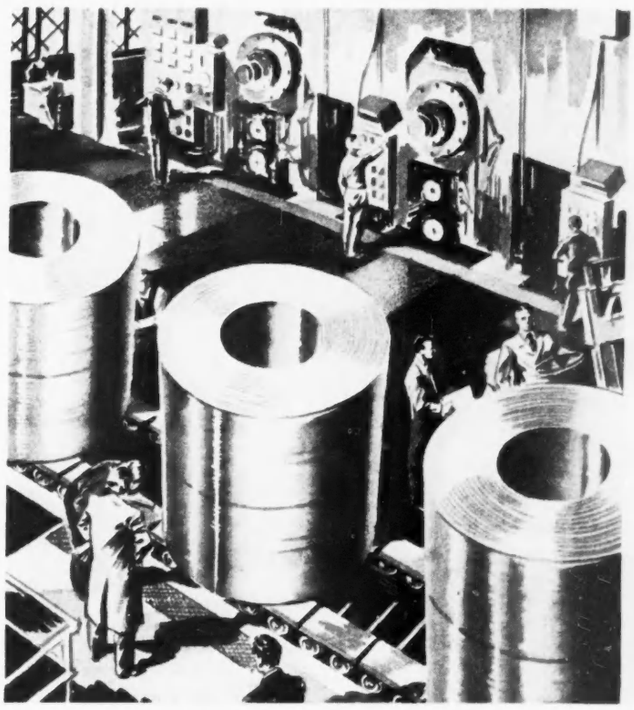

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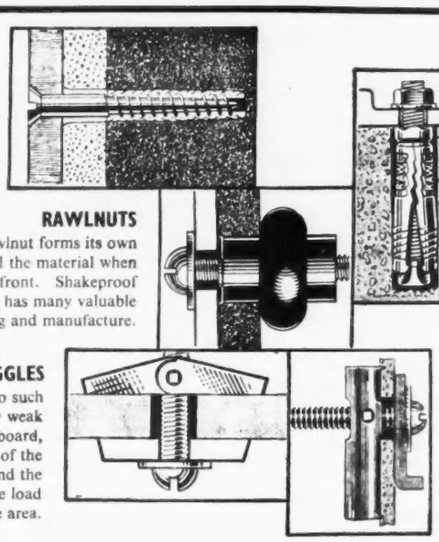

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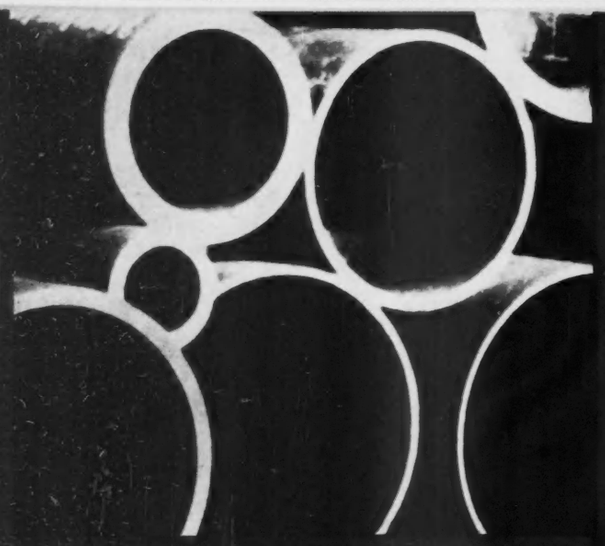

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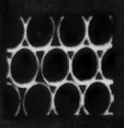

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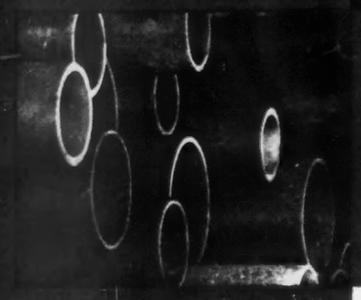

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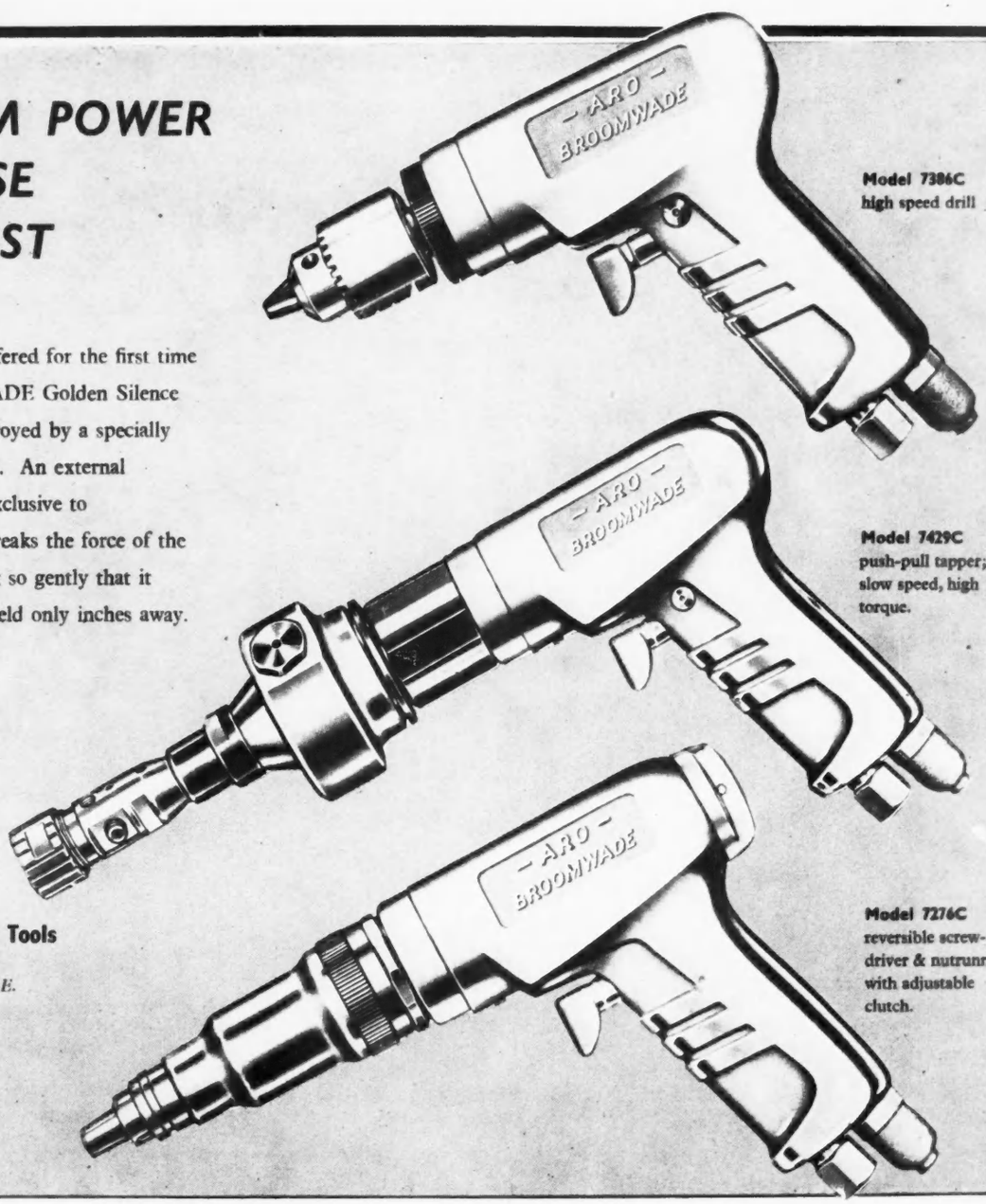

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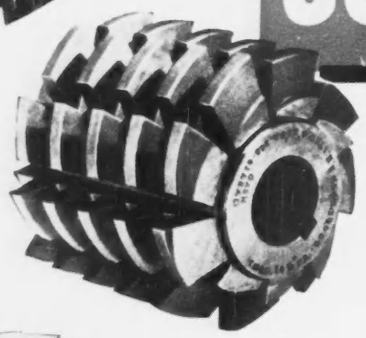

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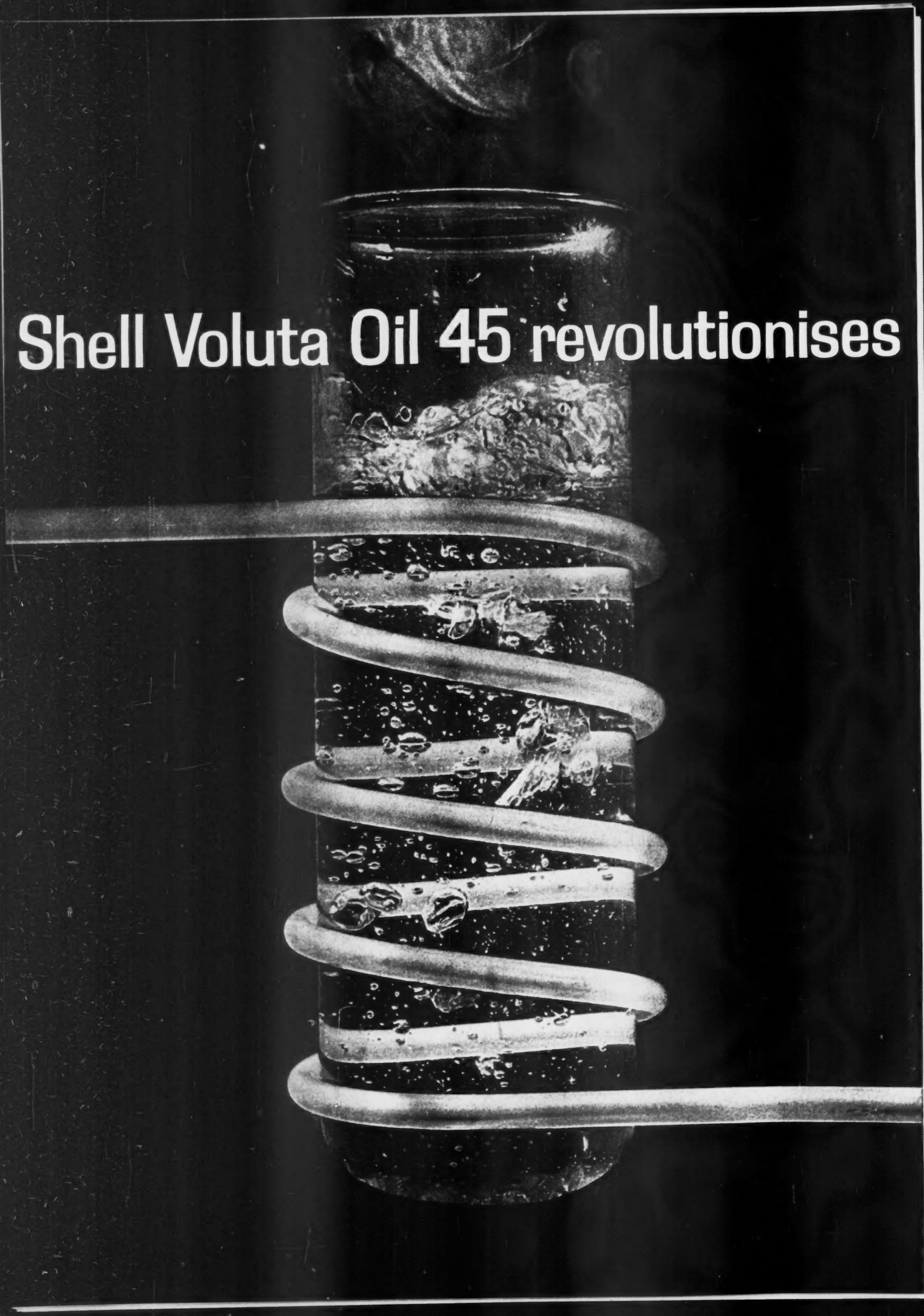

Shell Voluta Oil 45 revolutionises

heat exchange practice

Before Shell produced Voluta Oil 45 it was thought that oils which were to be used for heat exchange purposes must have a high flashpoint—to reduce fire risk—and a high viscosity to prevent excessive leakage through pump glands and to provide adequate lubrication for pump bearings at high temperatures. Heat exchange systems containing these viscous oils, however, were sluggish, particularly when started up from cold. The oil circulated slowly over the source of heat and suffered thermal decomposition, or "cracking". This, in turn, produced low flashpoint materials and carbon which insulated the heating surface.

Shell, therefore, began investigating the suitability of oils of lower viscosity and different chemical constitution. From this research was developed Shell Voluta 45.

Shell Voluta 45 contains hydro-carbons with a saturated ring structure which does not have the tendency that high viscosity straight chain paraffin hydrocarbons had—to break down at high temperatures. Because of its low viscosity Shell Voluta 45 heats up more quickly from cold and circulates more rapidly thus avoiding local overheating and thermal decomposition.

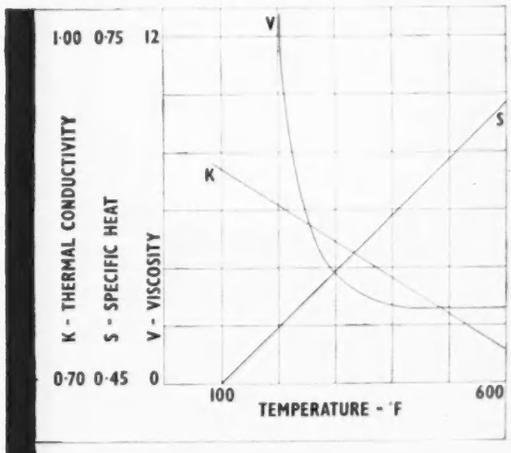
Shell Voluta Oil 45 has excellent heat transfer properties, good thermal stability and good lubricating properties. It is recommended for use in all closed heat transfer systems.

The moral of the story is that Shell research is supremely applicational. The centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organisation have any major lubricating problems, it pays to get in touch with your local supplier of Shell Industrial Lubricants.

The Research Story

Laboratory research to compare the high temperature performance of various oils in a rig simulating practical conditions showed that when oils of varying viscosities were maintained at an average temperature of 325°C. for 200 hours, the closed flashpoint of the high viscosity oils had dropped to a lower figure than that of oils of lower viscosity, indicating that some thermal decomposition had taken place.

Experimental oils were subjected to Heat Stability Tests and to tests designed to measure the variation in heat transfer coefficient with time. The most promising of these oils was then given extensive field trials, both in Shell Installations and in industry. From this extensive research was developed Shell Voluta 45.



Physical properties of Shell Voluta Oil 45.
K. Thermal Conductivity—B.T.U./sq. ft. per hour per 1°F. per inch.
S. Specific Heat—B.T.U. per lb. per 1°F.
V. Viscosity—Kinematic centistokes.

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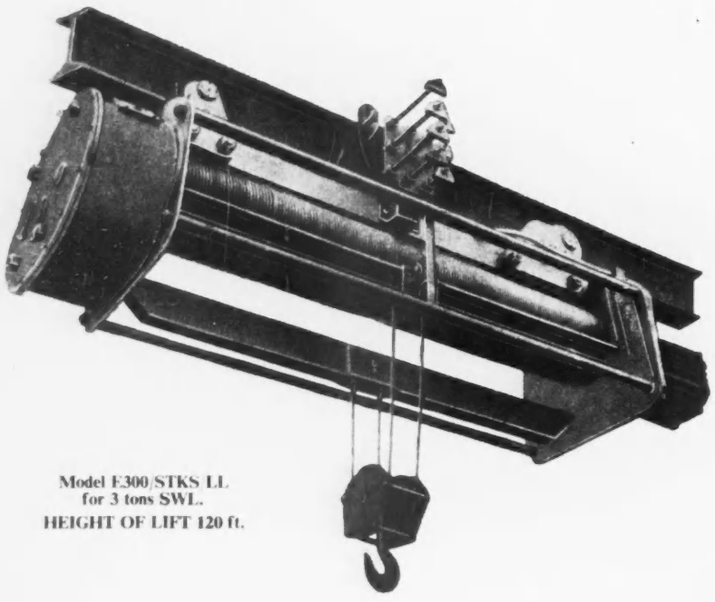

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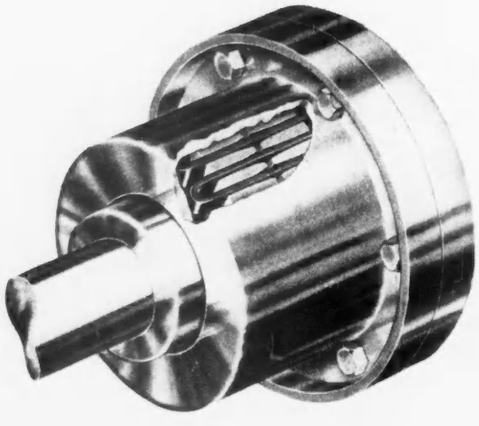

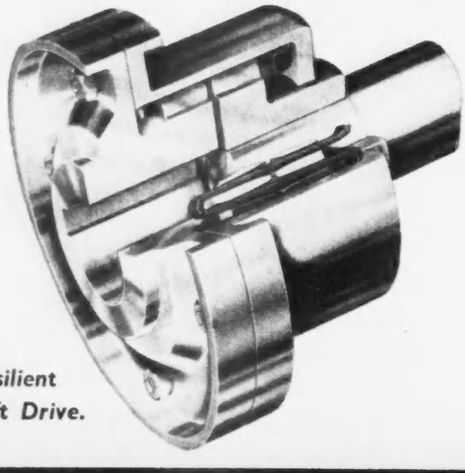

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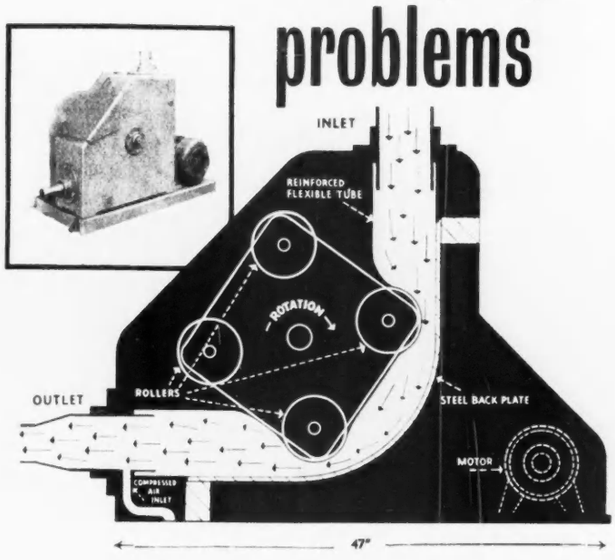

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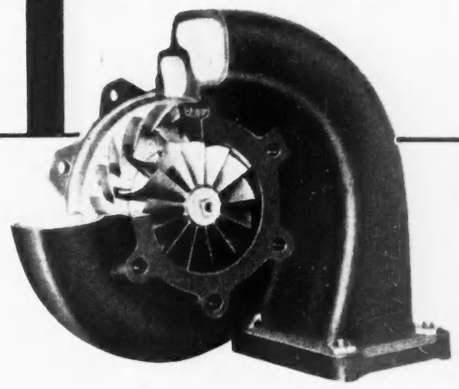

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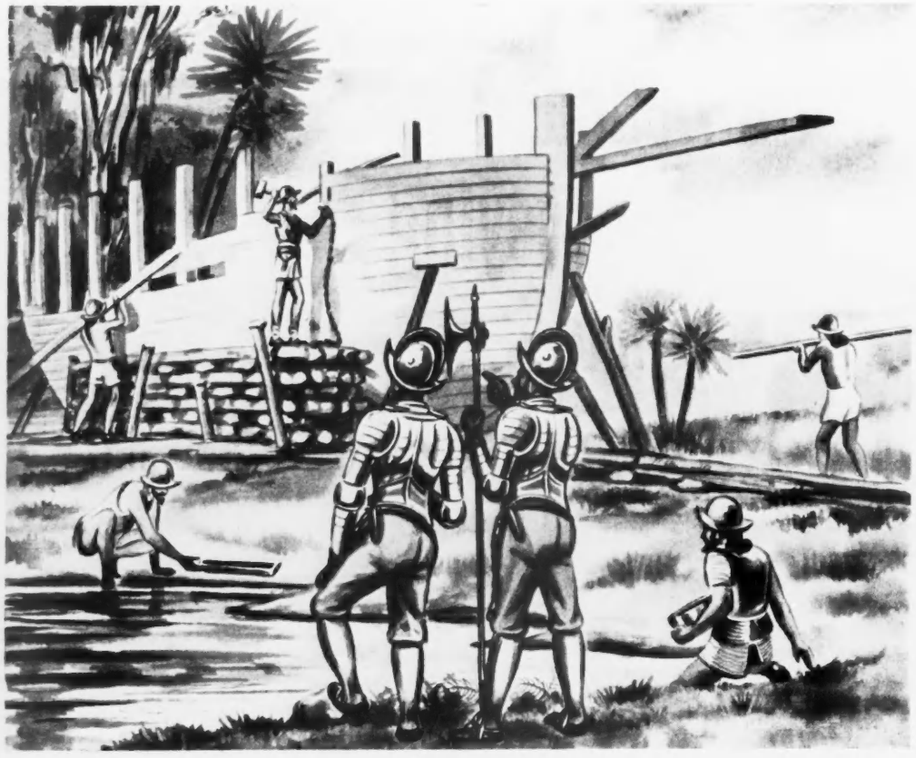

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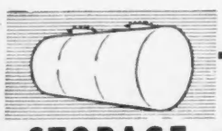
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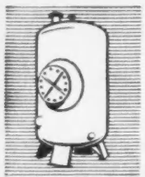

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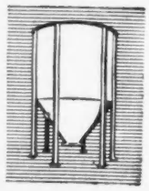

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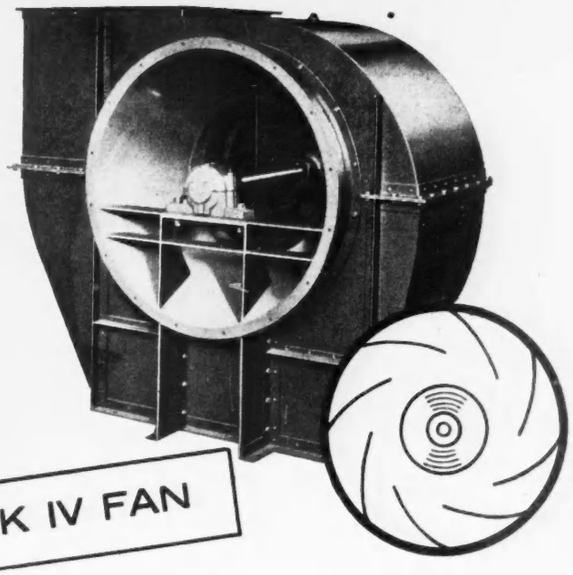

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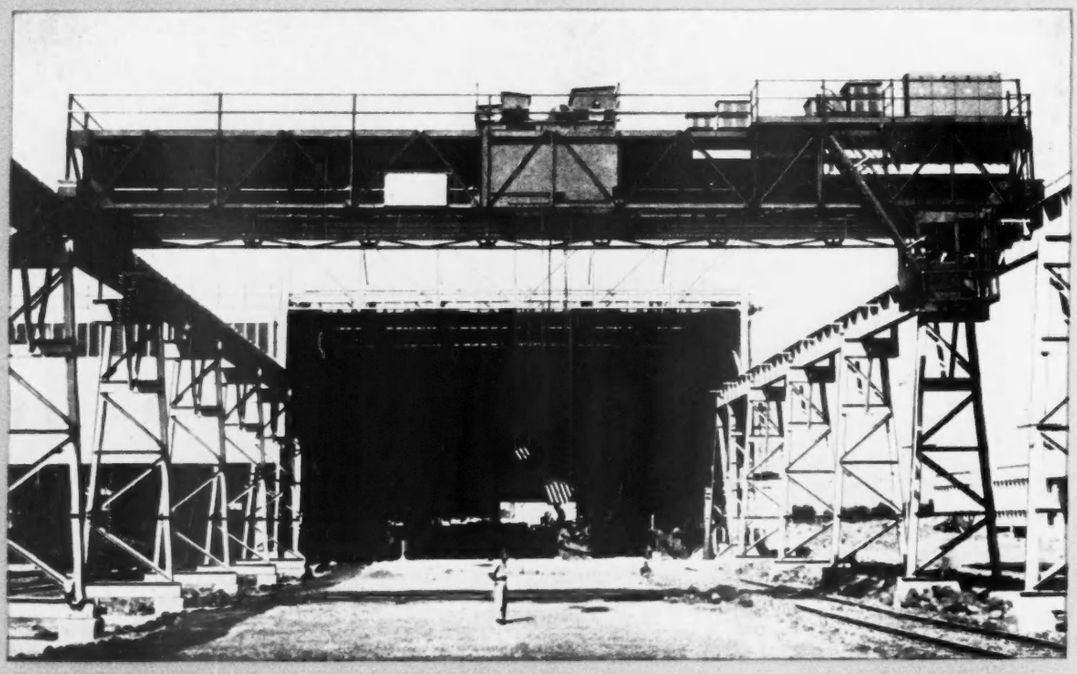

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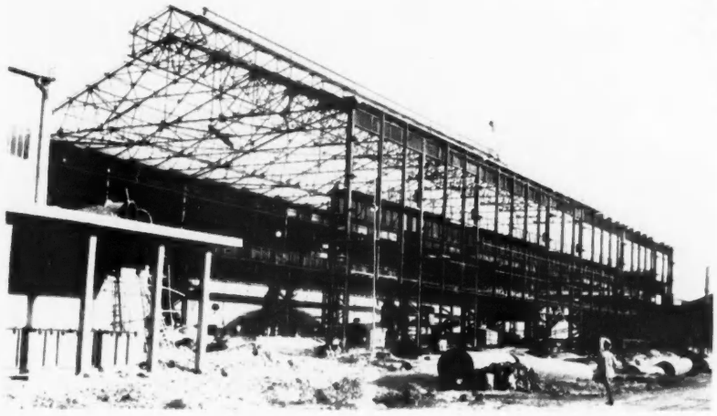

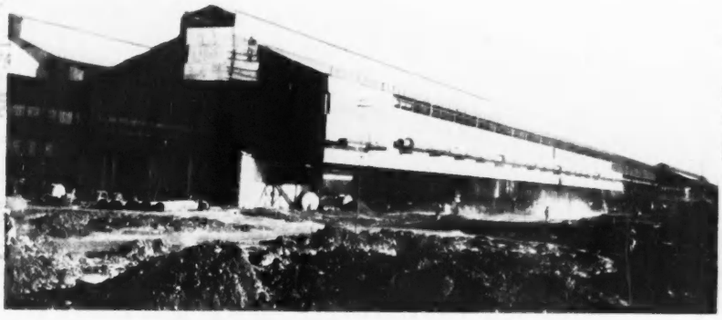

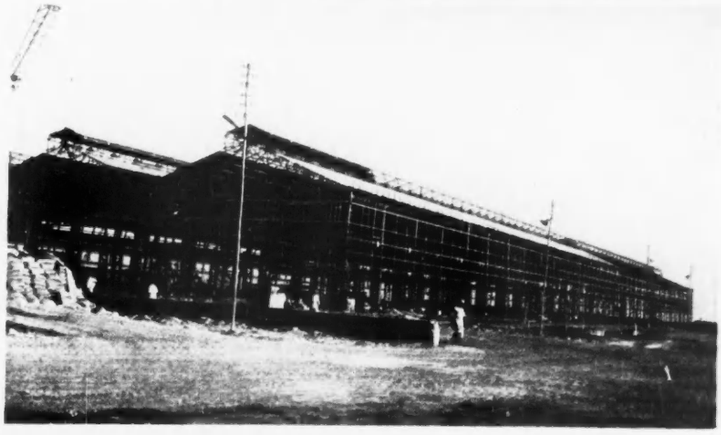

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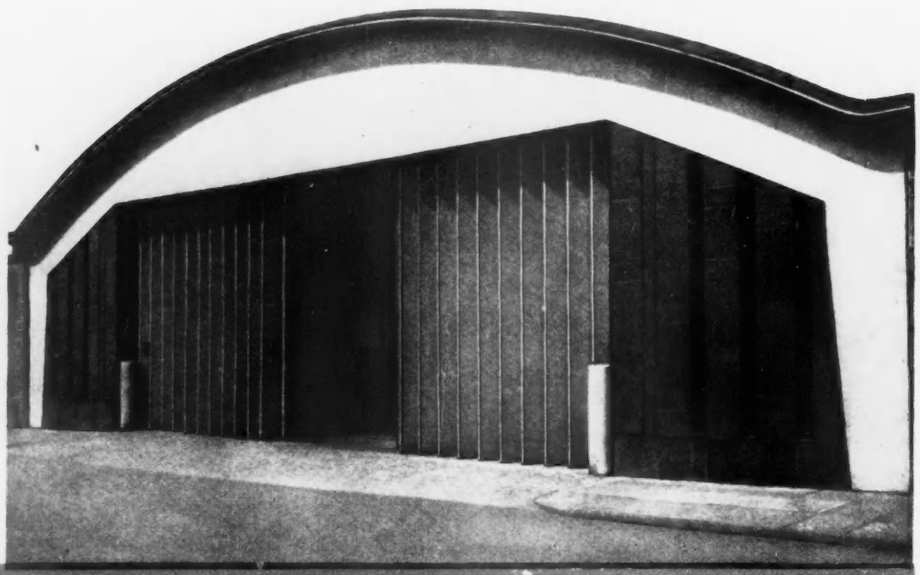

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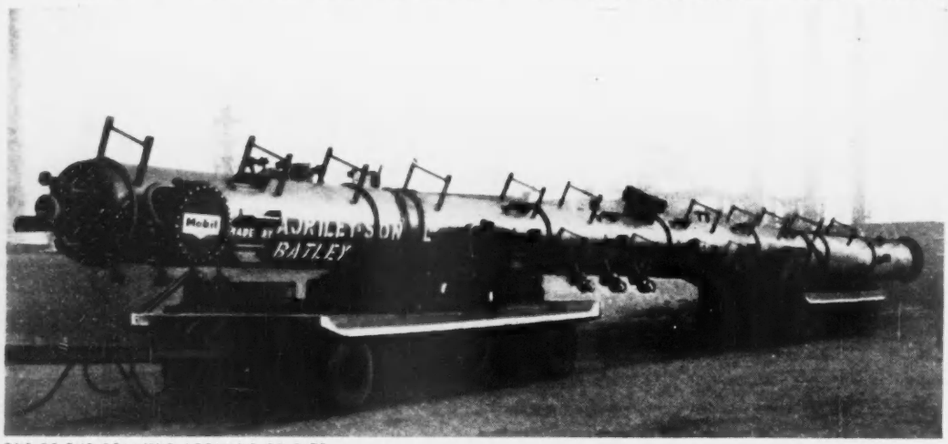
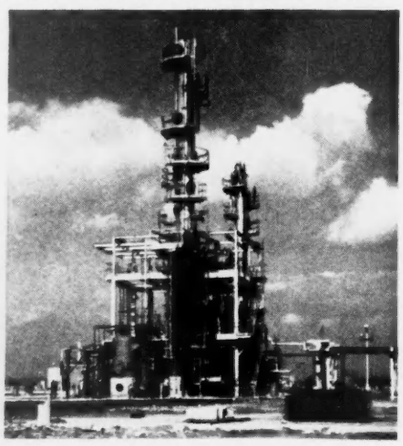


ONE OF THE COLUMNS ARRIVING ON SITE



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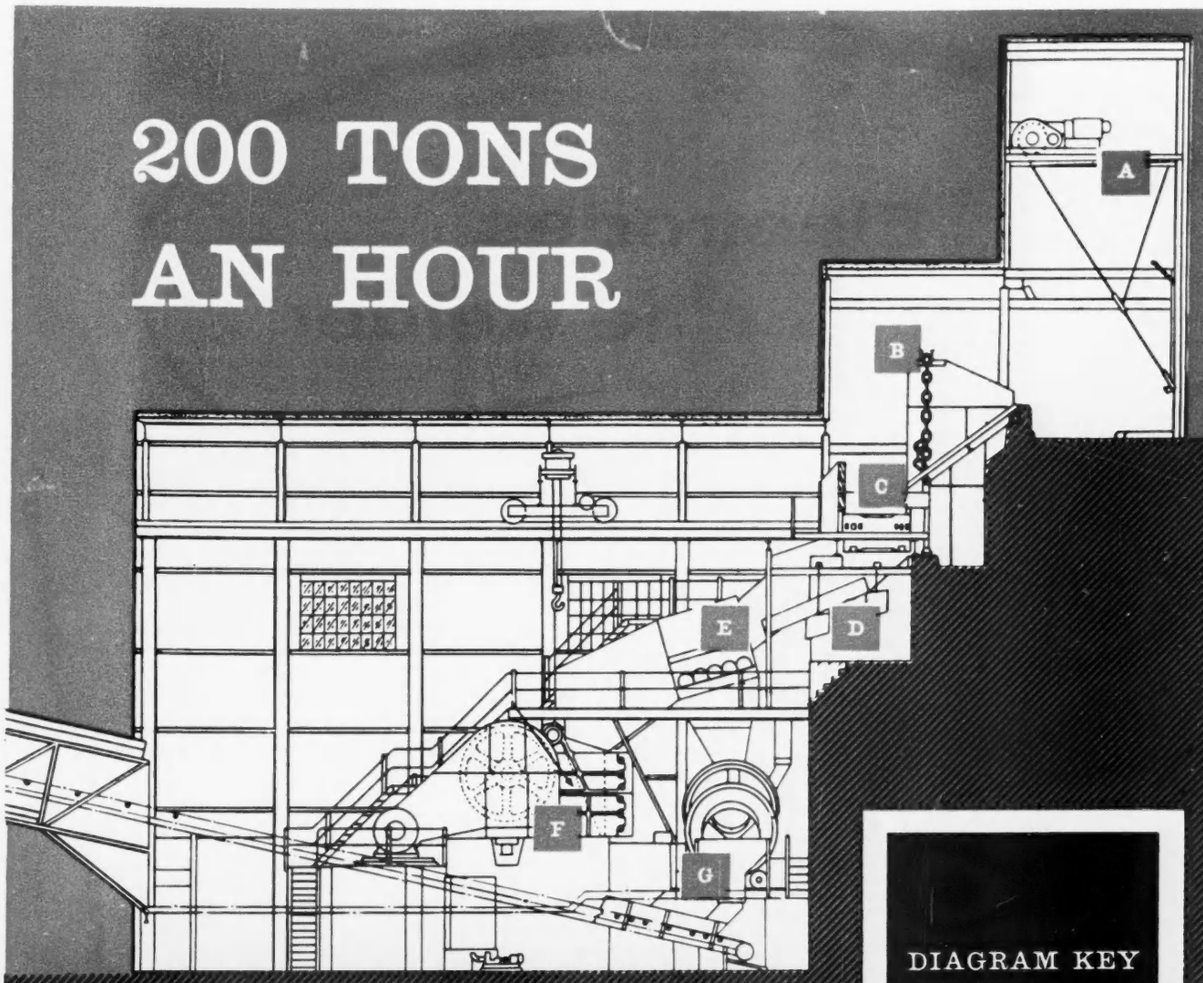

DIAGRAM KEY

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- B RECEIVING HOPPER
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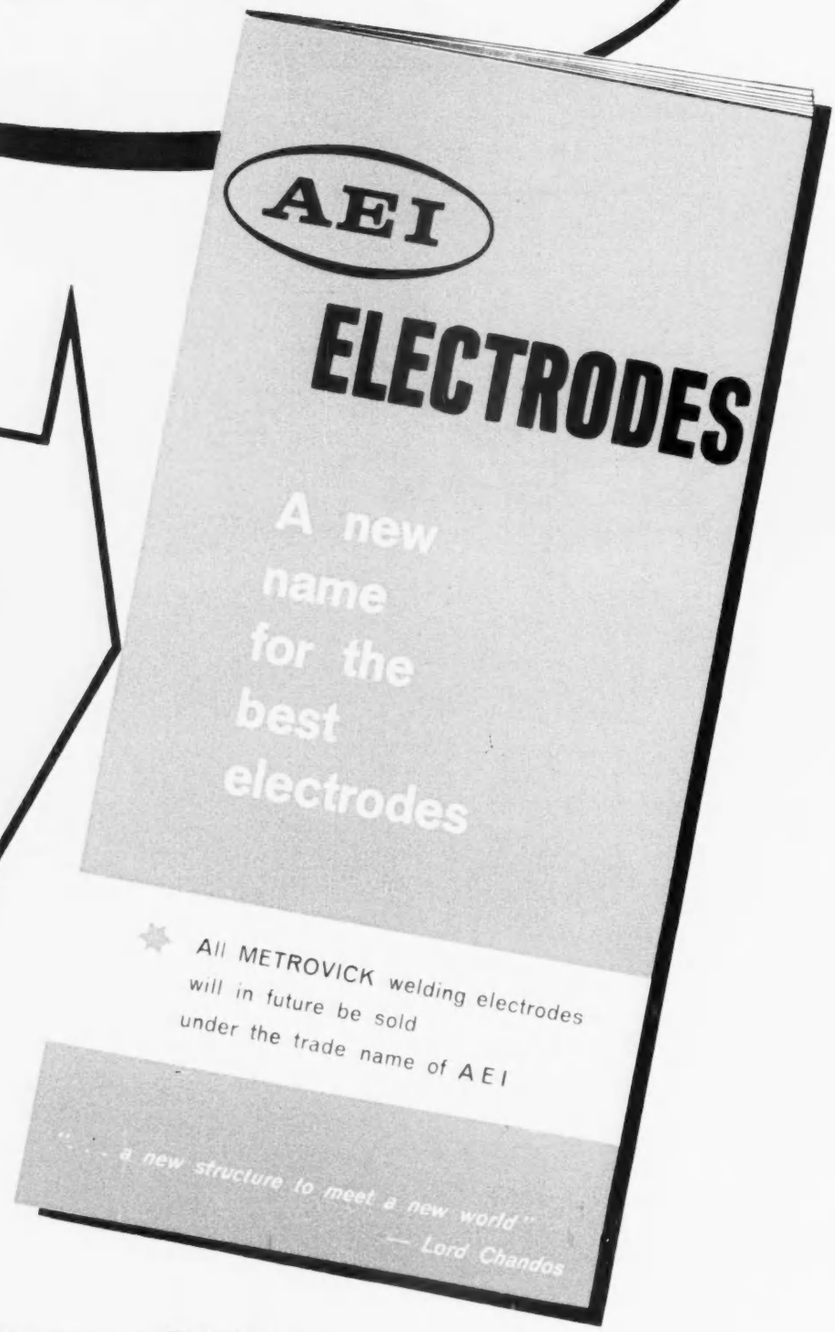
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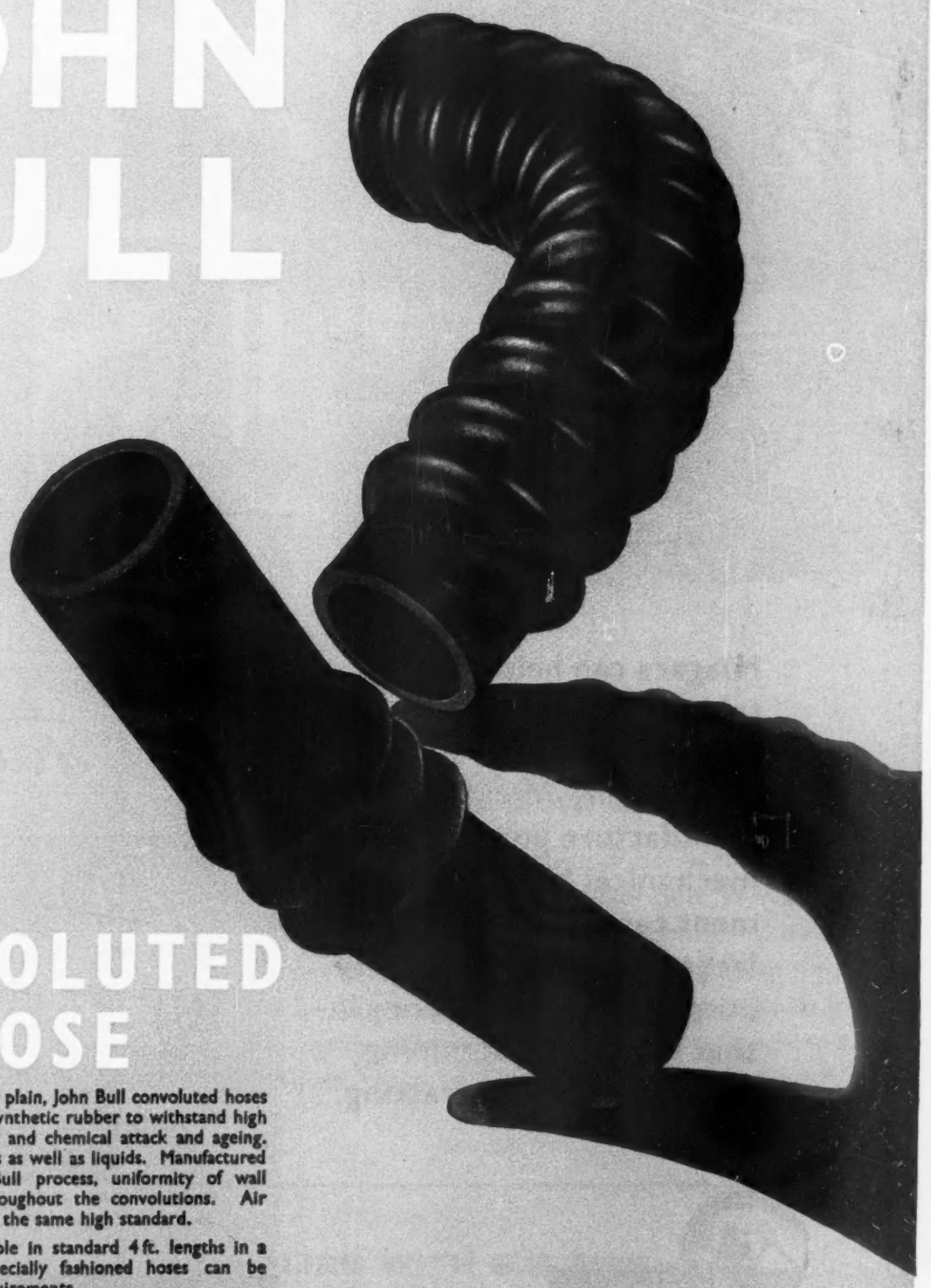

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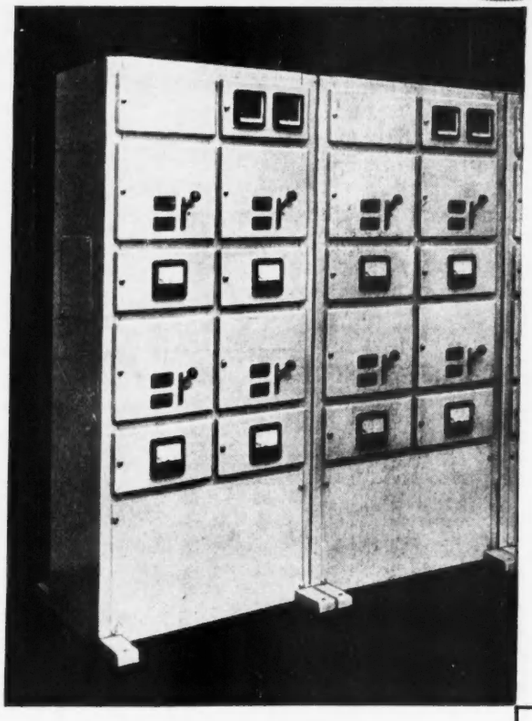

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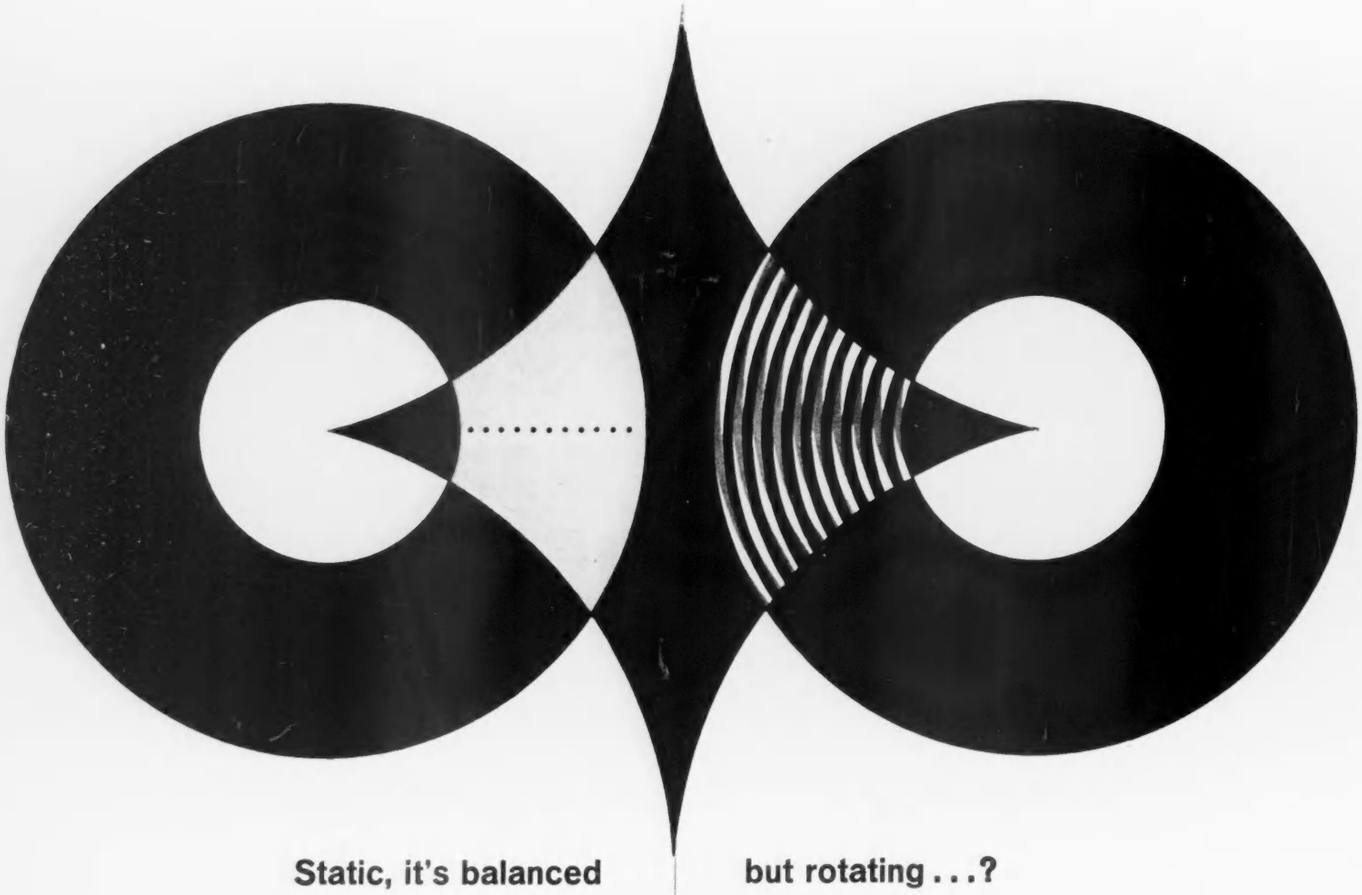
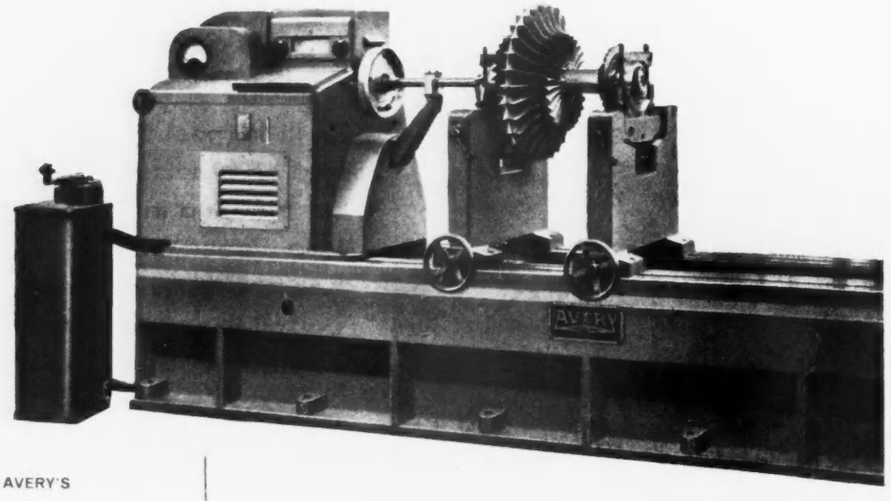


Static, it's balanced but rotating . . .?



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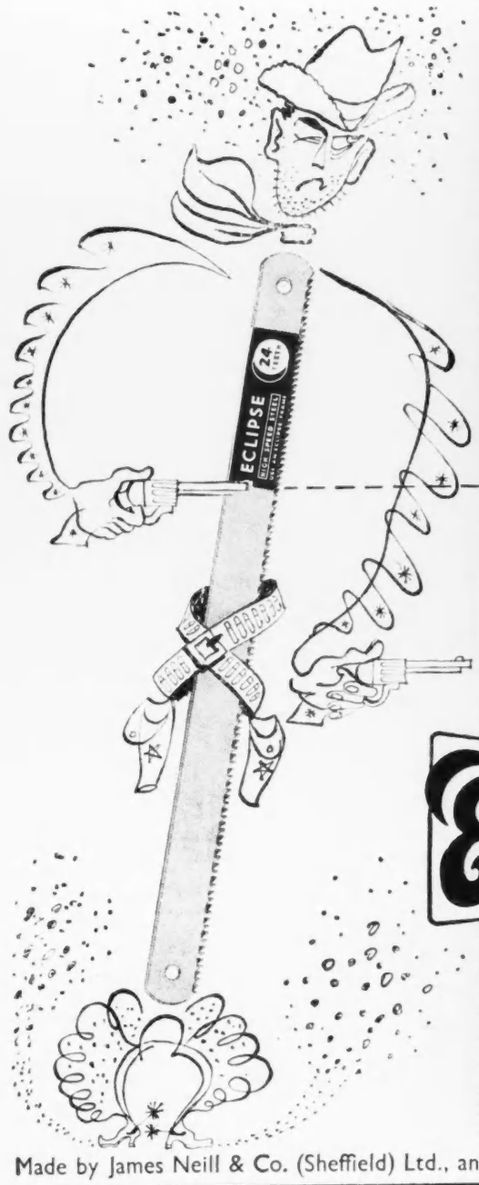

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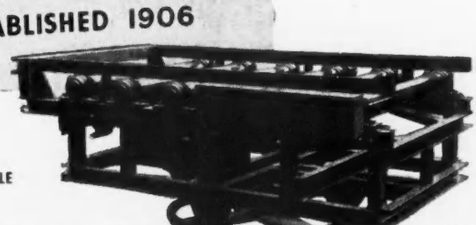

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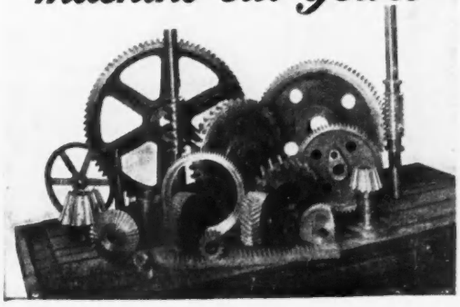

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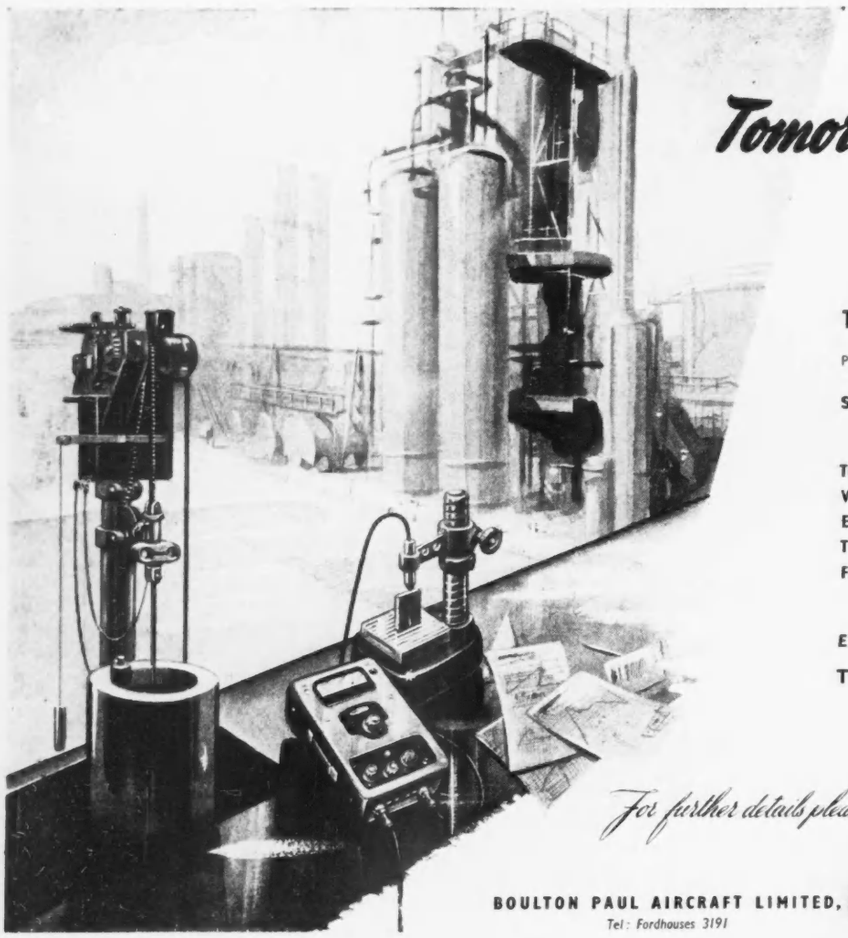

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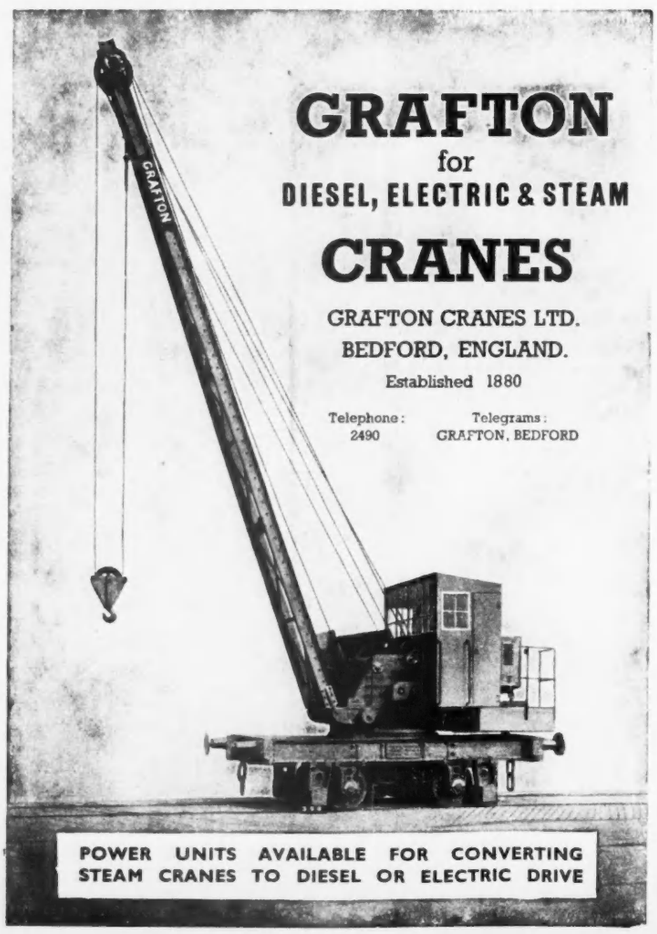

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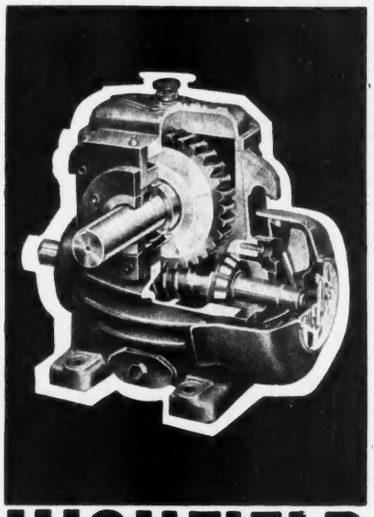

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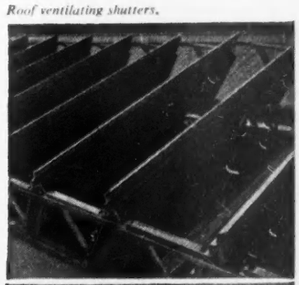

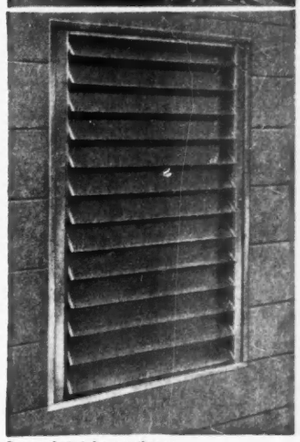

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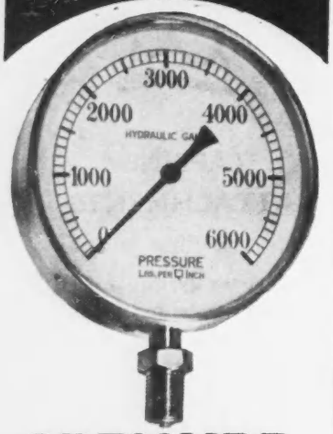

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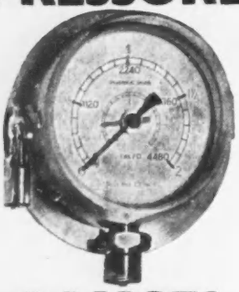

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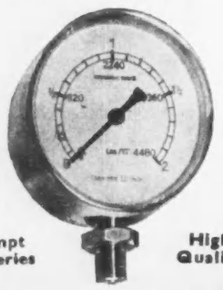

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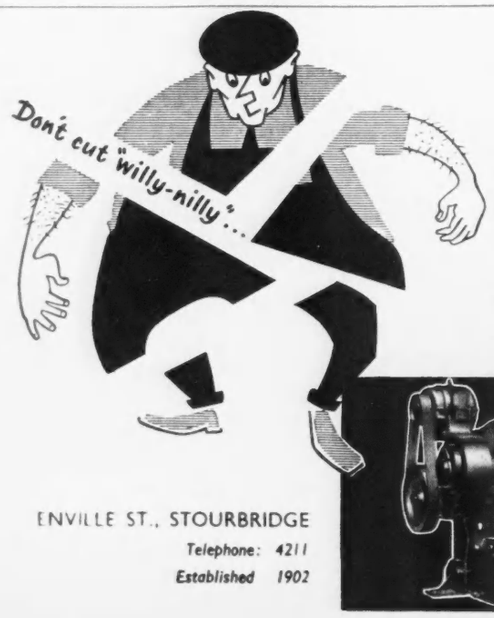

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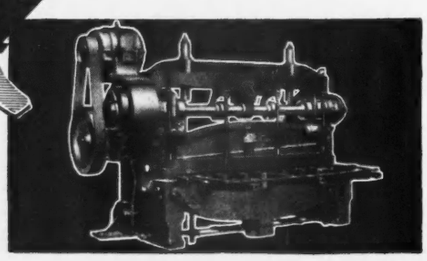

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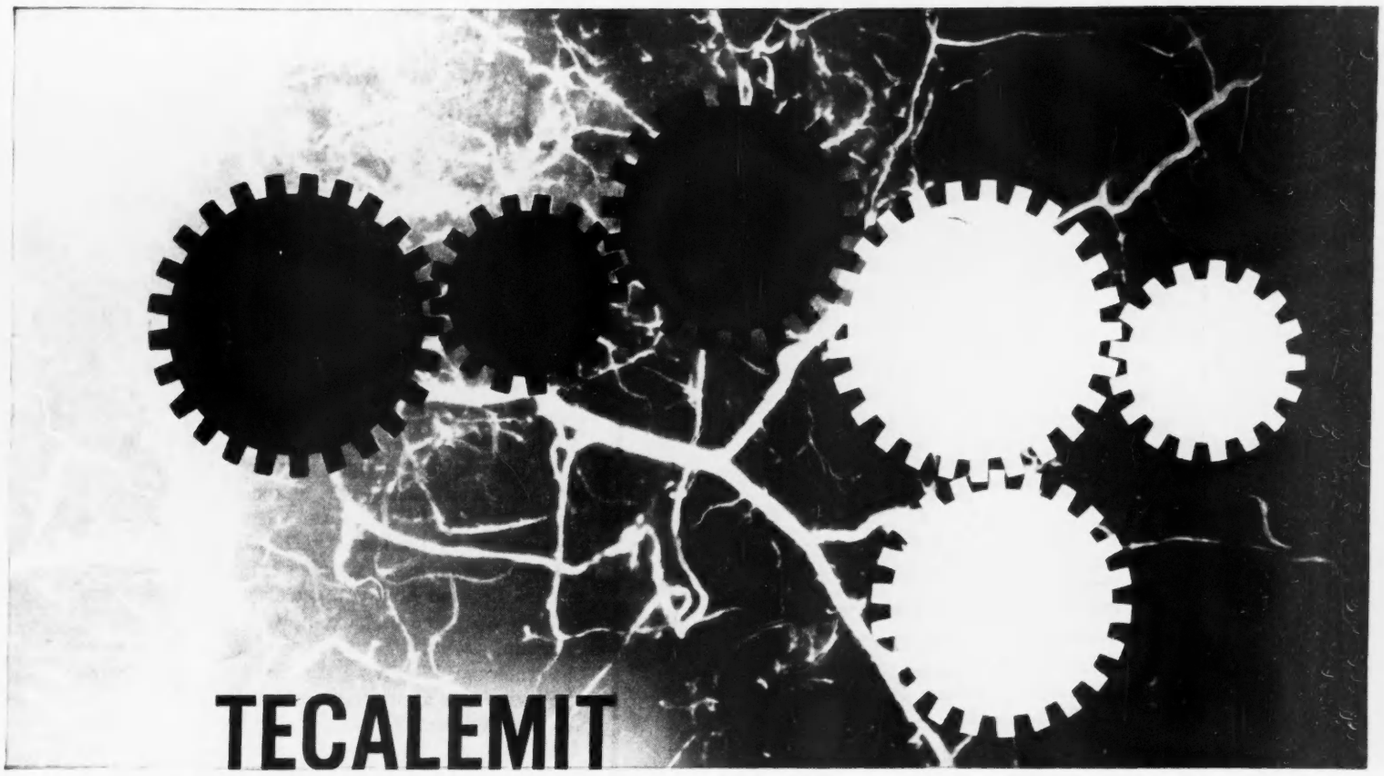

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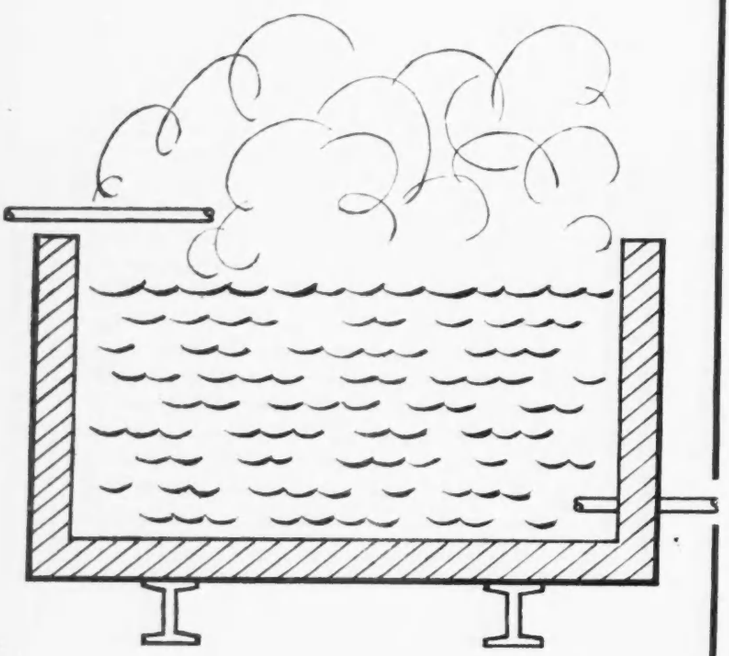

The boiler feed tank is one of the commonest pieces of industrial plant. It is also one of the most neglected.

There was a time when boiler feed tanks seemed to be designed, if at all, by rule of thumb—and thumbs can be of different lengths.

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Should hot condensate always be returned to the boiler feed tank? If there are exceptions, what are they? And is it really worth lagging the tank?

And engineers are sometimes both surprised and pleased to be reminded that, for every 11 °F rise in feed water temperature, the boiler needs about 1 per cent less fuel.

These may all seem very simple matters, and indeed they are. But they are still important factors in the efficient and profitable use of costly steam, and will repay careful study.

Our Information Sheet No. 14 discusses briefly and practically the boiler feed tank, and Information Sheet No. 21 treats of the wider associated subject of condensate return.

Copies of both are free to engineers who think we may have a point or two.

SPIRAX - SARCO

Please send . . . free copies of the Information Sheet "The Boiler Feed Tank"

. . . free copies of the Information Sheet "Condensate Return"

NAME

ADDRESS

EG 460 A

FUEL EFFICIENCY AND POWER FOR INDUSTRY
EXHIBITION
(GRAND HALL) **OLYMPIA**
April 27th-May 6th 1960

STAND 17 ROW F

Spirax-Sarco Ltd. Cheltenham Glos. Phone: Cheltenham 5173 Spirax Telex Cheltenham London: 28 Victoria Street SW1 Abbey 6101-3832

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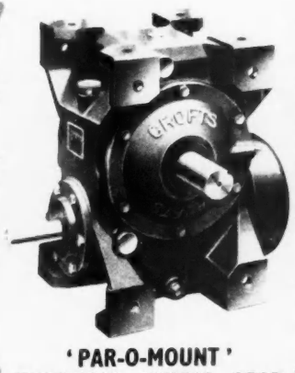
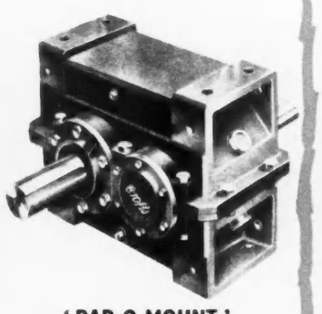
✳ These products are news - see them on Stand HH 12

MECHANICAL HANDLING EXHIBITION
EARLS COURT MAY 3rd—13th
FIRST FLOOR—WARWICK ROAD ENTRANCE



'PAR-O-MOUNT' UNIVERSAL WORM GEAR
Up to 5" centres and 25 h.p. Stock ratios 5 : 1 to 70 : 1.



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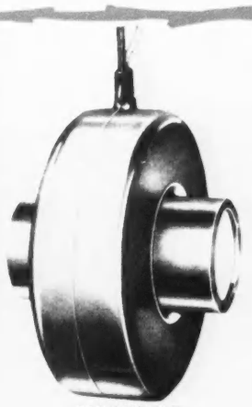
Up to 10" centres and 550 h.p. Ratios up to 6 : 1.



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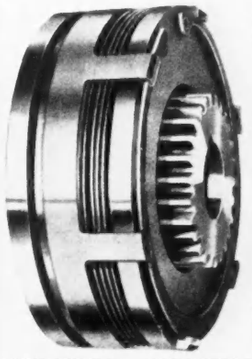
Standard range transmits torques from 4 to 420 oz ins. at speeds up to 20,000 R.P.M.



'AUTOJUST' MAGNETIC CLUTCHES AND BRAKES
For machine tool gearboxes. 13 sizes up to 50 h.p.

✳ plus a full standard range of power transmission equipment

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CROFTS (ENGINEERS) LIMITED

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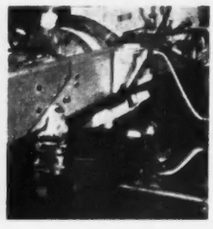
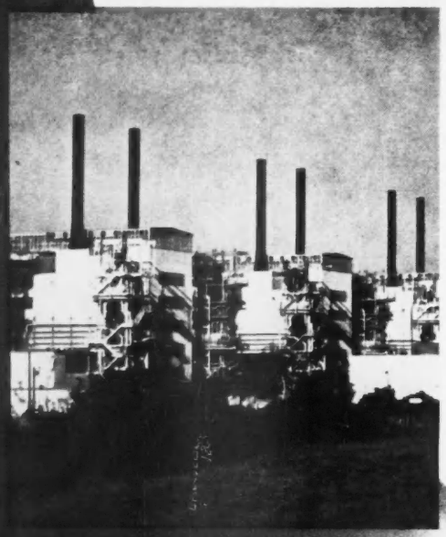
Colvilles Special Steels





developed for specific projects

ABRAZO	Abrasion Resisting Steel.
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FITNESS FOR PURPOSE STEELS

COLVILLES LIMITED 195 West George St., Glasgow C.2.

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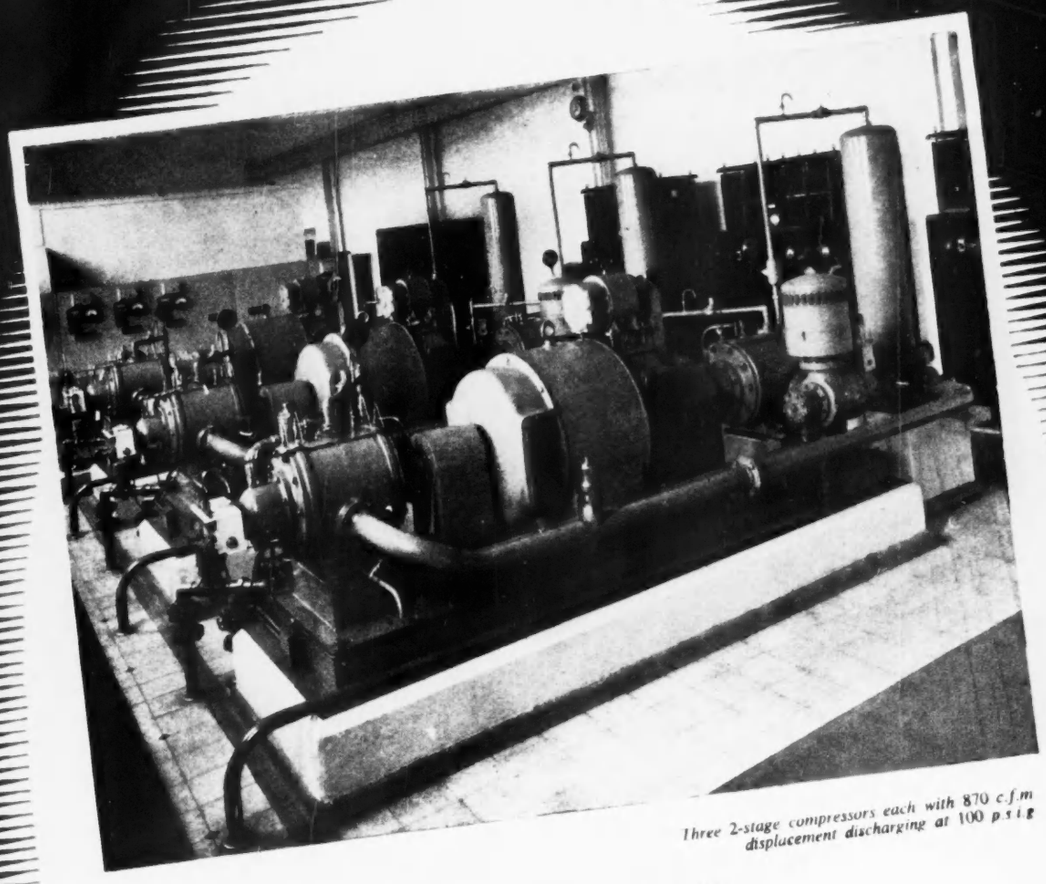

Three 2-stage compressors each with 870 c.f.m displacement discharging at 100 p.s.i.g

Rotary Compressors and Vacuum Pumps

The Hick Hargreaves Rotary Compressor is of the eccentric rotor type, with sliding steel blades which are prevented from making contact with the cylinder walls by restraining rings. High rotational speeds can thus be achieved without great frictional losses. Hick Hargreaves Rotary Compressors have many other advantages — easy and cheap installation; retention of initial high performance; regular air flow and low noise level; easy maintenance due to the absence of moving valves, and the reduction of wear to a minimum by the use of roller bearings.

A comprehensive range of both single and two-stage compressors and vacuum pumps is available with capacities up to 2,000 c.f.m.

Hick Hargreaves

AND COMPANY LTD · BOLTON

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PROTECTION...

Reyrolle ANNOUNCE A NEW PILOT-WIRE SYSTEM

Solkor-R

HIGH-SPEED FEEDER-PROTECTION

This system is a major advance in the art of feeder protection. It combines the most recent results of protection research with principles which have been well proved in service. Requiring only a single-pole relay and lightly insulated 2-core pilots it is both simple and economical to install, and, being based on static components, its maintenance costs are negligible.

Other features are high-speed operation, high transient stability, low fault-settings, use of ordinary current-transformers, and suitability for pilots up to 1,000 ohms resistance.

Ask for Pamphlet No. 1328

Reyrolle

A. REYROLLE & COMPANY LIMITED - HEBBURN - COUNTY DURHAM - ENGLAND

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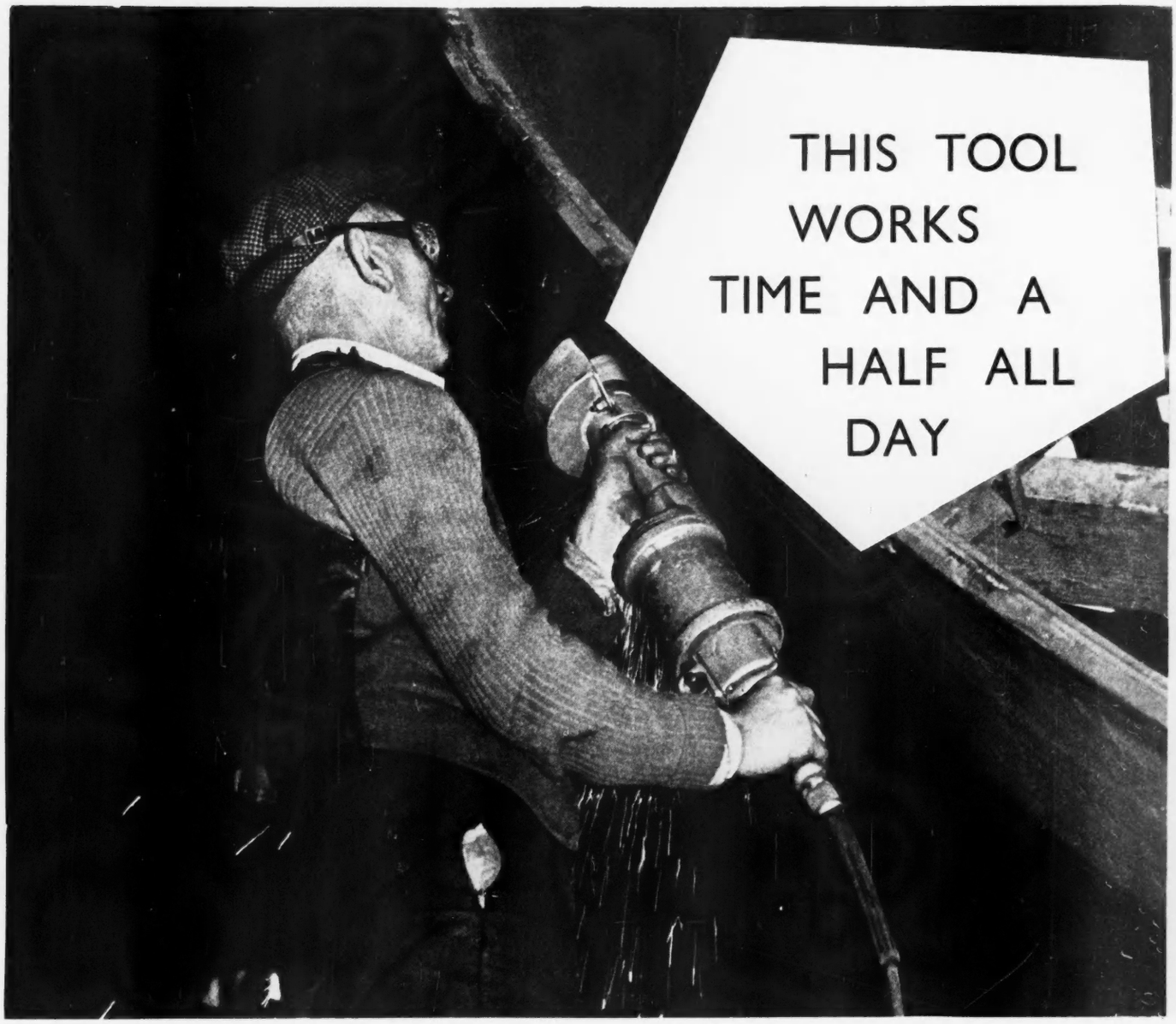

As much as 50% extra output each shift can be achieved by maintaining constant and correct grinding speeds throughout the job—each operator can turn out more work—and with less fatigue—it's as easy as that!
That's how Hicycle production tools work. There is virtually no speed drop under load and faster work is the result.
Ask for a catalogue describing the whole range of Hicycle tools including angle machines with cut-off wheels.

Hicycle
electric production tools by
CONSOLIDATED PNEUMATIC

GRINDING IS FAST
... VERY FAST!

CONSOLIDATED PNEUMATIC TOOL COMPANY LIMITED · DAWES ROAD · LONDON · S.W.6

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CRANKSHAFT GRINDING MACHINES

Let us quote against your requirements.

Available with swings of 50" and 67" or larger to suit work.

ELGAR EXCLUSIVE DISTRIBUTORS IN THE U.K.
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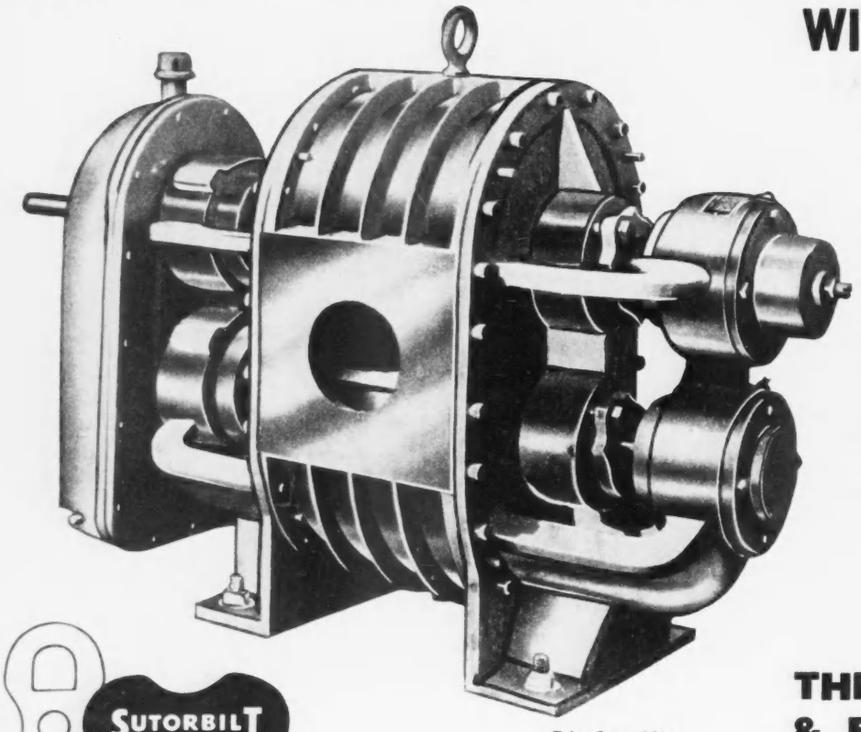
NEW "400" SERIES SUTORBILT ROTARY POSITIVE BLOWERS WITH OIL-FREE OPERATION



Because **SUTORBILT** Blowers require no internal lubrication, compressed air or gas is delivered OIL FREE. This is the most important feature in air conveyors handling food and chemicals in particular.

The new "400" Series blowers are available in 30 sizes, ranging FROM 10 c.f.m. TO 3,000 c.f.m., and pressures from ½ lb. p.s.i.g. to 10lbs. p.s.i.g. (or to 15 p.s.i.g. for special application).

Constructional features of the "400" series blowers include wide face herringbone gears, thus minimising wear and maintaining close impellor tolerances.

FOR PROMPT DELIVERY AND HIGH PERFORMANCE SPECIFY **SUTORBILT** DESIGN BLOWERS —EXHAUSTERS AND GAS PUMPS.

SUTORBILT
IS WELL BUILT

Tel : Cupar 2091
Grams : Foundry Cupar Fife

THE HILLSIDE FOUNDRY & ENGINEERING CO., LTD.
(CUPAR) LTD
CUPAR - FIFE - SCOTLAND

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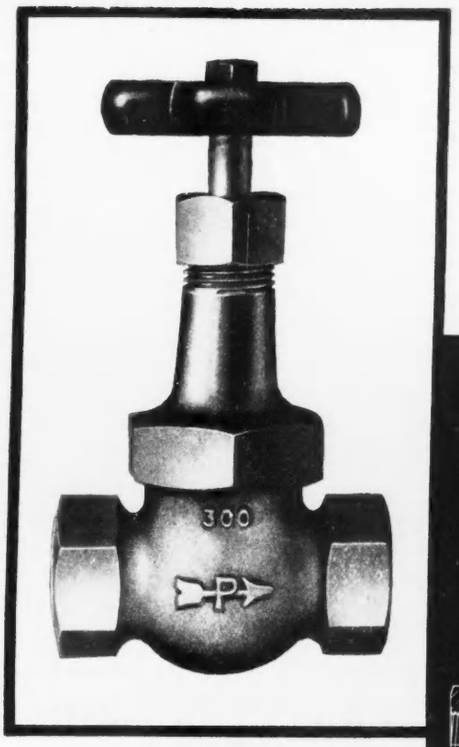
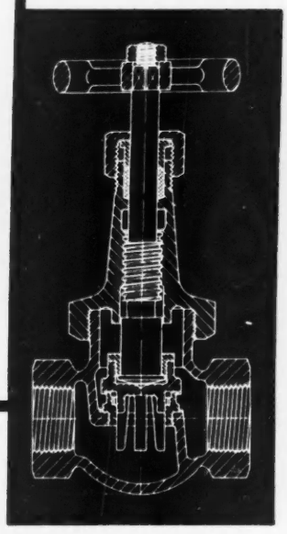


AT HIGH PRESSURES AND TEMPERATURES

the NEW Peglers steam stop valve 1028B is first in its class



Many unique design features, and manufacture to close limits, make this the most reliable valve of its class ever produced. The operational limit of 300 p.s.i. at 600 F is higher than the maximum required by B.S. 2060:1953. Renewable valves and seats are made in specially treated high quality stainless steel to ensure long life under the most exacting conditions.

- *Pressure tight joints. Ends screwed to B.S. 21*
- *Heavy bonnet reinforces body*
- *Circular seat supports for minimum flow resistance*
- *Expansion cavity prevents wire drawing on seat*
- *Skirt protects seat from solids in pipe line*
- *Alignment of spindle thrust maintained in service*
- *Large hexagons for simple servicing*
- *Available in a wide range of sizes*

Peglers Limited
The name is the guarantee

For detailed information, please write for new leaflet

PEGLERS LIMITED · DEPT. E · BELMONT WORKS · DONCASTER *Also at 28 Thorp Street · Birmingham, 5*
London Office and Warehouse : PRESTEX HOUSE · MARSHALSEA ROAD · S.E.1

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British & best

KING DICK
STILLSON
PIPE WRENCHES

King Dick Stillson Pipe Wrenches maintain the same high standard of quality expected with all our tools. The jaws are subject to a very rigid heat treatment control and are 100% hardness-tested to ensure reliability. All the individual parts are interchangeable. Available in 8", 10", 14", 18", 24", 36" and 48" sizes.
Write for illustrated leaflet.

BUY BRITISH

BINGDON KING DICK

ABINGDON KING DICK LTD.
Abingdon Works, Kings Road, Tyseley, Birmingham, 11, England.

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You are welcome to examine and discuss

NEW

Boiler House Equipment

at

STAND No. 9

ROW F, GROUND FLOOR, GRAND HALL

FUEL EFFICIENCY EXHIBITION

OLYMPIA—LONDON

27th APRIL – 6th MAY

Stop, Outside screw

Stop, Inside screw

Straightway

Spring relief

Parallel slide

Check

BRONZE VALVES

The Blakeborough range of small Bronze Valves provides a choice of thoroughly dependable types, sturdily built from high grade materials, and capable of long and economical service. They cover a variety of steam conditions up to 250 psi 500°F, according to type, and water generally up to 350 psi. Size range : globe screwed, ¼" to 3", flanged, ½" to 3"; gate valves, screwed or flanged, ½" to 3".

Reducing

BLAKEBOROUGH

J. BLAKEBOROUGH & SONS LTD., BRIGHOUSE, ENGLAND

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30 YEARS EXPERIENCE in

SMOOTH ACCELERATION

LIGHT LOAD STARTING

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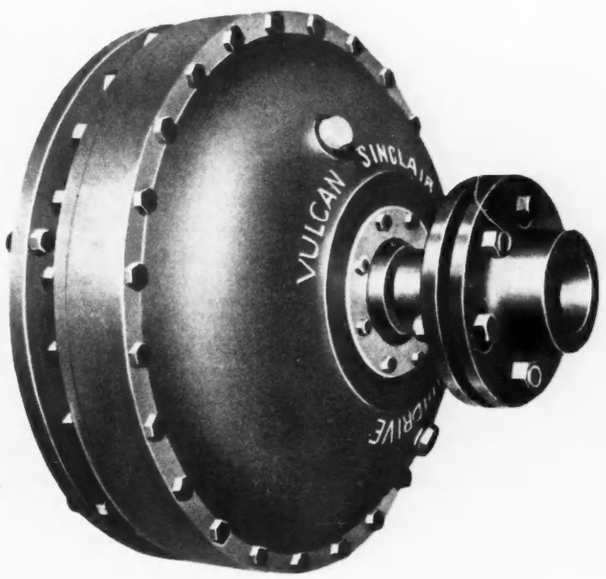
SHOCKLESS POWER TRANSMISSION

MINIMUM MAINTENANCE



VULCAN-SINCLAIR

Fluidrive

Illustrated brochure sent on request

brings to the user the maximum advantages in terms of simplicity overall performance and reliability. Established in more than 500 different industrial drives the Vulcan-Sinclair traction coupling is used in every major industry at home and overseas.

VULCAN-SINCLAIR FLUIDRIVE

FLUIDRIVE ENGINEERING COMPANY LTD.

Fluidrive Works, Worton Road, Isleworth, Middx.

Telephone : ISLEWORTH 1121 6 lines Telex : 24107

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CLASSIFIED ADVERTISEMENTS

PUBLIC APPOINTMENTS · SITUATIONS VACANT · TENDERS · EDUCATIONAL · BUSINESSES and PREMISES · BUSINESS OPPORTUNITIES PATENTS · MISCELLANEOUS · AGENCIES · DIRECTORS · PARTNERSHIPS

Lineage Rate. 4/6 per line of approximately 6 words. Minimum 18/–. **Inch Rate.** 54/– per single column inch and pro rata. 12 lines to 1 inch

There are reduced rates (i.e., not on a pro rata basis) for advertisements of ¼-page (12 column inches) and upwards, e.g., ¼-page £29 10s. ½-page £54. Full page £100.

FOR SALE · MACHINERY, etc., WANTED · AUCTION SALES · SITUATIONS WANTED · SUB-CONTRACTING · DESIGN SERVICES · FOR HIRE

Lineage Rate. 4/– per line of approximately 6 words. Minimum 16/–. **Inch Rate.** 48/– per single column inch and pro rata. 12 lines to 1 inch.

There are reduced rates (i.e., not on a pro rata basis) for advertisements of ¼-page (12 column inches) and upwards, e.g., ¼-page £25 10s. ½-page £48. Full page £90.

Run-On and Semi-Displayed Styles. Both these styles are available for single column width advertisements of any depth up to 12 inches.

Displayed and Illustrated Styles. The minimum size for a Displayed advertisement is 3 inches single column, for an illustrated advertisement it is a ¼-page (12 column inches). Thereafter the sizes for both progress in steps 3 inches deep across 1, 2, 3 or 4 columns.

Use of Box Number. 2/– which includes forwarding of replies.

Copy Dates. Tuesday for publication on Friday same week. If proofs are wanted, copy is required on Thursday for publication on Friday of the following week.

***Advertisements for publication should be addressed to*:—Classified Advertisement Dept., "THE ENGINEER," 28 Essex Street, Strand, London, W.C.2**

Urgent advertisements may be telephoned to CENtral 6565.

PUBLIC APPOINTMENTS

NORTH RIDING EDUCATION COMMITTEE

SCARBOROUGH TECHNICAL COLLEGE

ASSISTANTS

Applications are invited for the following posts, to take effect from September 1, 1960:

1. ASSISTANT, Grade "B," for Electrical Installation Courses. Ability to teach elementary Radio an advantage.

2. ASSISTANT, Grade "B," for Machine Shop Engineering and Mechanical Craft Practice Courses.

Forms and particulars available from me on receipt of stamped, addressed envelope. Completed forms to be returned by May 11th, 1960.

F. BARRACLOUGH.

County Hall,
Northallerton. E9588

LONDON COUNTY COUNCIL

WANDSWORTH TECHNICAL COLLEGE

THREE ASSISTANTS, GRADE "B"

Wandsworth Technical College require THREE ASSISTANTS, GRADE "B" to teach (i) Electrical Engineering subjects to at least S.3 level; (ii) Electronics to at least C. & G. final certificate level; (iii) Mathematics to H.N.C. standard (should be graduate in mathematics, knowledge of statistics an advantage). Posts (i) and (ii) from September, post (iii) as soon as possible.

Graduate or equivalent qualifications, industrial and teaching experience desirable. Burnham F.E. Salary scale £700 by £27 10s. to £1150, plus London allowance, and additions for training and qualifications. Increments within scale for experience.

Application forms from Secretary at the College, Wandsworth High Street, S.W.18, returnable by 13 May. (915). E9589

UNIVERSITY OF MANCHESTER

SENIOR LECTURER AND LECTURER IN ENGINEERING

Applications are invited for the posts of SENIOR LECTURER and LECTURER IN ENGINEERING (Mechanical). Preference will be given to candidates with a major interest in Applied Thermodynamics or Applied Mechanics especially Theory of Machines. Some experience of Mechanical Design would be an advantage. University regulations permit teaching staff to read for the Degrees of M.Sc. and Ph.D.

The salary scales (at present under review) per annum are as follows: Senior Lecturer, £1700 to £2050; Lecturer, £900 to £1650. Membership of F.S.S.U. and Children's Allowance Scheme. Initial salary according to qualifications and experience.

Applications should be sent not later than May 7th, 1960, to the Registrar, the University, Manchester, 13, from whom further particulars and forms of application may be obtained. Applications by air-mail letter, in the first instance, will be considered from overseas candidates. E9482

ARMY SCHOOL OF SIGNALS

CATTERICK, YORKS

SENIOR LECTURERS

ONE POST in PHYSICS and MATHEMATICS and ONE POST in TELECOMMUNICATIONS for men normally at least 30 on May 1, 1960, with honours degree, preferably at least 2nd class, in (a) Physics or Mathematics, or (b) Electrical Engineering or other relevant subject with experience in two of the following fields: telecommunications, electronic engineering, computers and electronic data transmission. For both posts lecturing ability up to approximately University degree standard essential. Salary: £1550 to £1750. Starting salary under Burnham conditions. Teacher's superannuation. Successful candidates to take up duty as soon as possible. Write Civil Service Commission, Burlington Gardens, London, W.1, for application form, quoting 5130/60. Closing date, 24th May, 1960. E9617

PUBLIC APPOINTMENTS

NORTH RIDING EDUCATION COMMITTEE

CLEVELAND TECHNICAL COLLEGE, REDCAR

ASSISTANT, GRADE "B"

Applications are invited for the post of ASSISTANT, GRADE "B," for Workshop Engineering Subjects, to take effect from 1st September, 1960. Forms and particulars available from me on receipt of stamped, addressed envelope. Completed forms to be returned by 11th May, 1960.

F. BARRACLOUGH.

County Hall,
Northallerton. E9636

LONDON COUNTY COUNCIL

TELFERSCOT SECONDARY SCHOOL, TELFERSCOT ROAD, EMMANUEL ROAD, S.W.12.

MASTER

Telferscot Secondary School, Telferscot Road, Emmanuel Road, S.W.12. (590 boys and girls 11-16; Headmaster.) Required: MASTER in charge of HANDICRAFT—to take Engineering (Scale II £150). Apply on form TS.9 (SR), obtainable from the Education Officer, T.S.2, County Hall, Westminster Bridge, S.E.1 (stamped, addressed envelope), and returnable to the headmaster at the school. (1053) E9620

H.M. DOCKYARD TECHNICAL COLLEGES

ASSISTANT LECTURERS (GRADE A or B)

Pensionable (non-contributory) posts for men: two in Electrical Engineering (Portsmouth and Rosyth); one in Mechanical Engineering (Rosyth); one (Grade A only) in English with a modern language (Chatham). Ability to help with other subjects essential. Appointment as soon as possible, preferably by September, 1960. Qualifications: University degree or equivalent, and ability to teach special subject to H.N.C. standard. Final year students may apply. Burnham scales for Technical Colleges (no deduction for pension). Write Civil Service Commission, Burlington Gardens, London, W.1, for application form, quoting 5125/60. Closing date 12th May, 1960. E9539

TRINIDAD AND TOBAGO ELECTRICITY COMMISSION

VACANCY FOR A SHIFT CHARGE ENGINEER

The Trinidad and Tobago Electricity Commission has a vacancy for a SHIFT CHARGE ENGINEER at the Penal Power Station.

Applicants should have experience in the operation of modern steam turbines, water-tube boilers and diesel generators, and must have Graduate Membership of the I.E.E. or I.Mech.E., or Associate Membership of the I.Mar.E., or the Higher National Certificate in Electrical or Mechanical Engineering or Second Engineer's M.O.T. Diesel and Steam Certificate or Charge Certificate, Royal Navy.

The annual salary is £1408, rising by three annual increments to £1537. This salary includes a payment for Shift Work.

A partly furnished house will be provided at a rent of £10 8s. 4d. per month, plus a small extra charge for heavy furniture.

An outfit allowance of £60 is paid on arrival in Trinidad.

First Class passage to Trinidad will be provided for the successful applicant, his wife and children up to a maximum cost of four adult passages. First Class leave passages to the United Kingdom will be provided every three years.

There is a Superannuation Scheme similar to the C.E.G.B. and Area Board's Scheme.

Information on Trinidad can be obtained from the West India Committee, 40, Norfolk Street, London, W.C.2.

Applications, giving full details of qualifications, age, experience, etc., together with copies of two recent testimonials, should be sent by Air Mail to reach the General Manager, Trinidad and Tobago Electricity Commission, P.O. Box 121, Port of Spain, Trinidad, W.I., by 15th June, 1960. E9631

PUBLIC APPOINTMENTS

CITY OF NOTTINGHAM

SEWAGE DISPOSAL DEPARTMENT

EXTENSIONS TO SEWAGE PURIFICATION PLANT

Applications are invited for the following positions:

(a) MECHANICAL AND ELECTRICAL ENGINEER to control the operation of a Power Station comprising six 550 h.p. dual fuel engines; generators and switch gear for 415 volt a.c. current used within the limits of the works; appurtenant auxiliary equipment and the repair workshops adjoining. The Engineer will be responsible also for the repair of all machinery in this modern sewage works and purification plant, and agricultural estate utilised for sludge disposal. Applicants should be suitably qualified. Salary is in accordance with A.P.T. Grade IV (£1065 to £1220).

(b) FIVE POWER STATION SHIFT ATTENDANTS with experience of power generation, and fully conversant with diesel gas engine operation and maintenance.

Salary in accordance with Grade VI of the Scheme of Conditions of Service for Miscellaneous Classes of Officers (£715 to £775 per annum) and is inclusive of shift working.

The appointments will be superannuable and successful candidates required to pass a medical examination.

The successful applicants will be required to reside in houses which will be provided by the Corporation in the vicinity of the works.

Applications, stating age, details of education, training, experience and qualifications, together with the names and addresses of two referees, should be addressed to The Manager, Sewage Disposal Department, Stoke Bardolph, near Nottingham, not later than Monday, 16th May, 1960.

T. J. OWEN,
Town Clerk.

The Guildhall,
Nottingham. E9602

AIR MINISTRY

ASSISTANT CIVIL ENGINEERS

Air Ministry requires ASSISTANT CIVIL ENGINEERS for engineering and administrative work on construction and maintenance of civil engineering and building projects (covering barracks, workshops, runways, roads, water supply, sewerage, drainage works, &c.) on R.A.F. and Civil Aviation Stations.

Starting salary: (According to age) £805 (at age 25) to £1095 (at age 34), thereafter rising annually to £1260, with increase for London and decrease for country districts. Additional increase of £75 per annum (within maximum of scale) after two years' approved service subject to age then being 27 or over and Corporate Membership of Institution of Civil Engineers being held. Good opportunities for acquiring experience overseas with appropriate allowances of up to £1500 per annum in addition to salary. Appointments long-term with good prospects of pensionable positions and promotion. Five-day week, paid annual leave on rising scale, initially 4 weeks and 2 days.

Qualifications: A.M.I.C.E. or Sections I and II of Institution of Civil Engineers or B.Sc. (Eng.) and in addition have had at least 2 years' civil engineering experience on staff of Government Department, Local Authority or firm of Consulting Engineers or Contractors of good standing. Natural born British subjects.

Forms from Ministry of Labour, Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting E 184/0A. E9607

MINISTRY OF LABOUR

NATIONAL PHYSICAL LABORATORY

TEDDINGTON, MIDDLESEX

EXPERIMENTAL OFFICERS ASSISTANT EXPERIMENTAL OFFICERS

National Physical Laboratory, Teddington, Middlesex, requires EXPERIMENTAL OFFICERS/ASSISTANT EXPERIMENTAL OFFICERS in Design Office. Work involves design of apparatus and experimentation in wide range of physics, e.g. very high pressures, nuclear physics, optical instruments for experiments in animal and human psychology and electro-mechanical devices for high-speed electronic computers. H.N.C. (Mechanical Engineering) or equivalent qualifications, with design experience.

Salary ranges: E.O. (at least 26): £1005–£1233; A.E.O.: £442 (age 19) to £710 (age 26) to £880.

Forms from Ministry of Labour, Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting C338/0A. Closing date, 20th May, 1960. E9606

PUBLIC APPOINTMENTS

TRENT RIVER BOARD

APPOINTMENTS OF ASSISTANT ENGINEERS AND LAND SURVEYORS

Applications are invited for the following appointments in the Engineer's Department. N.J.C. service conditions with car allowance on "Essential User" Scale and Assisted Car Purchase Scheme is operated by the Board. The commencing salaries within the Grades mentioned below will be according to qualifications and experience, but normally appointments will be made in the lower half of the ranges.

Applications, including copies of testimonials or names of two referees to The Engineer, Trent River Board, 206, Derby Road, Nottingham, by 23rd May, 1960.

HEAD OFFICE, NOTTINGHAM.

(a) ASSISTANT ENGINEER I.

Salary: A.P.T. Grades III-V (£880–£1375).

The Engineer appointed will be engaged mainly on the design of major river improvement works and preference will be given to university graduates with previous experience of land drainage. A small house in Nottingham will be made available to the successful applicant on a rental basis.

(b) LAND SURVEYOR (Hydrology).

Salary: A.P.T. Grades I-III (£610–£1065).

The successful applicant will be engaged mainly on river gauging and surveys. Previous experience of river gauging is not essential as adequate training will be given.

DIVISIONAL OFFICES.

(c) THREE POSTS, one in each of the Divisional Offices at Tamworth, Nottingham and Gainsborough, and applicants should state their willingness to be appointed to all or any of these offices.

ASSISTANT ENGINEER II.

Salary: A.P.T. Grades I-III (£610–£1065), or Special Grade (£785–£1070).

The successful applicants will be engaged mainly on the design and supervision of river improvement schemes carried out by either contract or direct labour. Applications from University students who expect to graduate this year will also be considered.

DIVISIONAL OFFICE, TAMWORTH.

(d) LAND SURVEYOR.

Salary: A.P.T. Grades I-III (£610–£1065).

The successful applicant will be employed mainly in taking cross-sections of rivers and general topographical surveys.

IAN DRUMMOND,
Clerk of the Board.

E9622

NATIONAL COAL BOARD

EAST MIDLANDS DIVISION

WORKSHOPS MANAGER

WORKSHOPS MANAGER required by National Coal Board, East Midlands Division, for Area Engineering Workshops, situated near Chesterfield. The works employ approximately 430 men and are engaged chiefly upon the reconditioning of mining machinery and plant.

Applicants should have suitable technical qualifications and a proved general engineering background, and have held responsible positions requiring organising ability. They should be able to produce evidence of the successful application of modern production, planning and industrial management methods in all their aspects.

Salary in accordance with age, qualifications and experience within the range £1250–£1850 a year.

Applications, giving age, present post and salary and full details of qualifications and experience, should be sent to Area Staff Manager, National Coal Board, East Midlands Division, No. 1 Area, Bolsover, near Chesterfield, Derby, within seven days. Envelopes and applications should be marked S.V.1049. E9625

MINISTRY OF AVIATION

GLASCOED, MONMOUTHSHIRE

TECHNICIAN

Ministry of Aviation requires TECHNICIAN at Glascoed, Monmouthshire, to develop and specify inspection methods and procedure for conventional and new weapons. Preparation of process charts and flow diagrams; writing inspection instructions; responsibility for installation planned methods and training of inspection staff in their operation.

Qualifications: Recognised engineering apprenticeship; H.N.C., or equivalent qualification. Good experience of methods of manufacture. Knowledge of work study techniques and production planning an advantage. Salary: £1005–£1220 per annum.

Forms from Ministry of Labour, Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting C.352/0A. E9605

PUBLIC APPOINTMENTS

GOVERNMENT OF WESTERN NIGERIA

VACANCIES FOR ARCHITECTS

Applications are invited for the posts of ARCHITECTS.

Qualifications : Candidates who should be between 25-50 years of age, must hold a degree or diploma of a recognised School of Architecture and Associateship of Royal Institute of British Architects, and should have had not less than two years' practical experience since qualifying.

Duties : Design and preparation of working details of Building projects as directed, and supervision of drawing office staff in connection with these schemes. Site survey work and supervision of buildings in progress.

Terms of Appointment : On contract terms with gratuity, for a minimum of two tours of 12-18 months each, in the first instance. Salary is within the range of £1536-£2286 per annum, according to experience since qualifying, plus gratuity at the rate of £37 10s. for each completed three months' service. Free first class passages for officer and his family on first appointment and when proceeding on leave ; free medical treatment for officer and his family. Accommodation is provided at low rentals.

Applications should be completed in triplicate on the prescribed form obtainable from the Official Secretary (Recruitment Branch), Office of the Commissioner for Western Nigeria, 178-202, Great Portland Street, London, W.1, from whom further particulars may also be obtained.

Closing date : 4th May.

E9590

THE LONDON HOSPITAL

ENGINEERING DRAUGHTSMAN

ENGINEERING DRAUGHTSMAN, salary in range of £750-£1000 p.a. Requirement is for a sound, general engineering background with technical design experience supported by practical training. Applicant should have full appreciation of services distribution, heating and ventilating fundamentals and associated equipment. Age unimportant, but essential that applicant should be active and alert.

Write to Chief Engineer, The London Hospital, Whitechapel, E.1. E9630

WEAR AND TEES RIVER BOARD

SENIOR ASSISTANT ENGINEER— A.P.T. GRADE III

SENIOR ASSISTANT ENGINEER, A.P.T. GRADE III (£880–£1065 p.a.).

Applications are invited for the above vacancy from Chartered Civil Engineers or Graduates with experience in the design and execution of river improvement schemes. A good knowledge is required of survey work and hydraulic and structural calculations. Experience of direct labour work is desirable. The commencing salary will be fixed in accordance with experience and qualifications. The successful candidate will be required to provide and maintain a car not exceeding 10 h.p. (1199 c.c.) with N.J.C. Essential Users' Allowances. Assistance in the purchase will be given if required. The appointment is pensionable and will be subject to the Local Government Superannuation Act, 1953, and to medical examination. Assistance in obtaining a house to rent can be given to persons not already residing in the Darlington area. Application forms are obtainable from the Chief Engineer, Mr. C. Clay B.Sc., A.M.I.C.E., at this address and should be returned to him not later than 12th May, 1960.

J. E. LAVEN,
Clerk and Chief Financial Officer.

"Greencroft East,"
158, Coniscliffe Road,
Darlington. E9626

WEST KENT MAIN SEWERAGE BOARD

SENIOR AND JUNIOR ENGINEERING ASSISTANTS

Applications are invited for :
(a) SENIOR ENGINEERING ASSISTANT—Engineering Special Grade (£785–£1070) ;
(b) JUNIOR ENGINEERING ASSISTANTS (TWO)—A.P.T. I (£610–£765).

The London Weighting Allowance (£10, £20, or £30 p.a.) is payable and the Local Government Superannuation Acts apply to the appointments. The Board's District covers 172 square miles ; the population exceeds 600,000. Current work includes new main sewers in tunnel and the design and construction of new purification works.

Applicants for position (a) must be graduate members of the Institution of Civil Engineers or University graduates with not less than five years' experience. For the positions (b) experience of general engineering drawing office practice is required.

Applications, with full personal details, particulars of education, training and experience and the names and addresses of two referees, to William Howard, B.Sc., M.I.C.E., Engineer to the Board, by 11th May, 1960.

A. J. W. JEFFERY,
Secretary of the Board.

20, Blyth Road,
Bromley, Kent. E9604

REPUBLIC OF IRAQ

CIVIL AND MECHANICAL ENGINEERS

The Directorate General of the Iraq Sewerage Board invites applications from suitably qualified Engineers for appointment to the following posts :
(1) CIVIL ENGINEER, to act as Deputy Resident Engineer on major sewerage schemes now under construction in Baghdad. Applicants should hold an Engineering Degree (or equivalent) and have had site experience of sewerage and sewage treatment works construction. Basic salary I.D.300 per month.
(2) MECHANICAL ENGINEER for site and office work in connection with drainage schemes in Iraq. Applicants should hold an Engineering Degree (or equivalent) and have had experience in the design, preparation of drawings and specifications, and checking of Tenders for the following mechanical plant of drainage schemes :
Full Sewage Treatment Works (Activated Sludge and Filtration Plants), Power Generating Plant, Vertical and Horizontal Sewage Pumps.

Applicants should also have had experience in the erecting, checking, operation and maintenance of the above equipment. Basic salary : I.D.250–270 per month.

The appointments will be for two years and will be subject to the standard Contract of Employment of non-Iraqi Officials, which may be seen at the address below. I.D.1 equals £1 sterling.

Application forms may be obtained from Messrs. John Taylor and Sons, Consulting Engineers, Artillery House, Artillery Row, London, S.W.1. Completed forms must be returned to Messrs. John Taylor and Sons at the above address by Wednesday, the 18th May, 1960. Applicants placed on the short list must be available for interview in London about the 24th May. E9611

CITY OF NOTTINGHAM

APPOINTMENT OF CITY ENGINEER AND SURVEYOR

Applications are invited from persons who have the necessary experience and qualifications for the appointment of CITY ENGINEER AND SURVEYOR, at a salary of £3340, rising by one increment of £115 and two further increments of £110 to £3675 per annum.

The gentleman appointed will be required to devote the whole of his time to the duties of the office and will not be permitted to hold any other appointment or engage in any other work.

The appointment carries superannuation and the selected applicant will be required to pass a medical examination and to contribute to the superannuation fund.

Applications, stating age, previous experience and present position, accompanied by two testimonials and the names of two persons to whom reference can be made, must be delivered to me not later than the last post on the 18th May, in an envelope endorsed "City Engineer."

T. J. OWEN,
Town Clerk.

The Guildhall,
Nottingham. E9562

NORTH EAST DERBYSHIRE JOINT WATER COMMITTEE

TECHNICAL STAFF

Applications are invited for the following appointment on the staff of the Engineer and Manager.

The commencing salary will be in accordance with qualifications and experience.

The appointment offers good experience in waterworks design and construction.

SENIOR ASSISTANT ENGINEER
(A.P.T. Grade IV : £1065–£1220.)

Applicants must be Corporate Members of the Institution of Civil Engineers and they should have had previous experience in the design and construction of service reservoirs, treatment plants and pumping stations.

Housing accommodation will be made available to the successful applicants and a car allowance will be paid up to 8 h.p. in accordance with the National Scale.

The post is superannuable and the successful applicant will be required to pass a medical examination.

Applications, stating age, qualifications, experience and appointments held, together with the names of two referees, should be submitted to the undersigned not later than 14th May, 1960.

H. O. HAWKINS,
Clerk.

Rural Council House,
Saltergate,
Chesterfield. E9571

DRAUGHTSMAN

required by

NORTH THAMES GAS BOARD at WESTMINSTER, S.W.1

for the design and detailing of reinforced concrete structures and foundations associated with gas works.

Higher National Certificate is a minimum qualification.

Starting salary according to qualifications and experience.

The appointment will be of a permanent nature and the successful candidate will be required to join the Board's contributory pension scheme.

Applications, stating age, qualifications and experience, should be sent to the Staff Controller, North Thames Gas Board, 30, Kensington Church Street, W.8, quoting reference TE/767. E9642

BOOKS and PUBLICATIONS

BLACKWOOD'S

IRON & STEEL TRADES CALCULATORS

With the object of providing users of these Calculators with a more useful service, in view of present prices of commodities, we are preparing and publishing revised volume giving a greatly extended range of calculations. *ready MAY* 1960

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,, ,, 1d.—1/- cwt. ,, ,, 10/- — 400/- ,, **45/-**
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"A complete library in two volumes . . ."

KEMPE'S ENGINEERS YEAR-BOOK

Edited under the direction of the Editor of "The Engineer"

1960 Edition price **87/6** *(plus postage 2/6)*

from technical booksellers or direct from the publishers

Kempe's Engineers Year-Book, 28 Essex Street, Strand, London, W.C.2
Telephone : CENtral 6565

Enter No. 1012 on reply card

HOSPITAL BUILDING PROGRAMME

SHEFFIELD REGIONAL HOSPITAL BOARD

ARCHITECTS ENGINEERS QUANTITY SURVEYORS

The Board require additional professional and technical staff to deal with a substantial expansion of the hospital building programme. This offers exceptional opportunities to those interested in contemporary design in a variety of buildings ranging from staff housing to the design of complete new hospitals. Promotion prospects are bright, and to those with creative ability and enthusiasm, a worthwhile career in a highly rewarding field is assured.

The Board's Headquarters are three miles from the City centre on the edge of the Derbyshire moors. Working conditions in modern drawing offices are excellent. Canteen and social facilities are available. Posts are superannuable and mileage allowances will be paid to approved car users.

Vacancies exist for :

Post	Salary Scale
Assistant Regional Architect	Salary to be determined
Principal Assistant Architect	£1665/£2035 per annum
Senior Assistant Architects Senior Assistant Quantity Surveyors } ...	£1300/£1600 per annum
Assistant Architects Assistant Quantity Surveyor } ...	£905/£1310 per annum

Architects should be members of the R.I.B.A. and Quantity Surveyors members of the R.I.C.S. Commencing salaries for new entrants at minimum of the scale.

Vacancies also exist for heating and ventilating engineers. Starting salary of £1160 for A.M.I.Mech.E., and £910 for A.M.I.H.V.E. Starting salaries for engineering draughtsmen vary from £550 to £1030 according to qualifications and experience.

Professional staff interested in an appointment in the hospital service should apply within ten days to the Secretary, Sheffield Regional Hospital Board, Fulwood House, Sheffield, 10. Applications should state qualifications, age, experience and post(s) in which interested, and should include the names of two persons to whom reference may be made.

E9616

Classified Advts. continued on page 102

TENDERS

BOROUGH OF CAERNARVON

ABER BRIDGE RECONSTRUCTION

TENDERS are invited from firms experienced in bridge reconstruction for the STRENGTHENING and IMPROVEMENT of ABER SWING BRIDGE and the Approach Roads to the Bridge. The bridge, which is of steel construction, carries one line of road traffic and is about 250ft. long, the swing span being about 150ft. long.

The works include the replacement and strengthening by welding of certain bridge members, the provision of timber footways, steel road deck and macadam surfacing, the replacement in cast iron of the roller paths and rollers, alterations to the operating mechanisms and the improvement of the approach roads.

Instructions to persons Tendering and documents may be obtained from the Consulting Engineers, F. R. Bullen and Partners, Dacre House, Dean Farrar Street, Westminster, S.W.1, on payment of £5 5s. deposit, returnable upon receipt of a bona fide Tender.

Applications for Tender documents should be made to the Consulting Engineers by 10th May, 1960.

On and after 2nd May, 1960, drawings may be inspected at the offices of the Borough Engineer and Surveyor, Swyddfa'r Dref, High Street, Caernarvon, or at the offices of F. R. Bullen and Partners, either in London or at 42, Victoria Road, Darlington, Co. Durham, without payment.

Tenders are to be delivered to the undersigned in a plain, sealed envelope before 12 o'clock noon on 14th June, 1960.

J. O. SMITH,
Town Clerk, Borough of Caernarvon.

Town Clerk's Office,
Briggs Chambers,
Caernarvon. E9613

HYDROELECTRIC PROJECT

CORPORACION AUTONOMA REGIONAL DEL CAUCA CALI, COLOMBIA

PREQUALIFICATION JULY 15, 1960

PREQUALIFICATION QUESTIONNAIRE

NOTICE TO CONTRACTORS

It is expected that during the second half of 1960 the Corporacion will request bids from a selected list of prequalified contractors for the construction of the Calima Hydroelectric Project, near Cali. The project will include a Rockfill Dam with a maximum height of about 100 metres and a volume of about 2,000,000 cubic metres ; an 120,000 kW Underground Powerhouse with a Vertical Access Shaft about 230 metres deep and an Inclined Access Tunnel about 700 metres long ; a Morning Glory Spillway ; a Power Intake and Gate Shaft, a Power Tunnel and Inclined Penstock Shaft ; a Tailrace Tunnel about 1630 metres long ; a Diversion Tunnel 660 metres long ; a Tributary Diversion Tunnel 7 kilometres long ; and appurtenant works.

Interested firms that have satisfactorily performed comparable work should apply promptly for prequalification forms to the Corporacion, Apartado Aereo 2366, Cali, Colombia. Completed prequalification forms will be required no later than July 15, 1960. Bids will be received from prequalified bidders only. E9632

COUNTY COUNCIL OF ESSEX

GRAYS HALL YOUTH CENTRE AND YOUTH EMPLOYMENT BUREAU

PROVISION OF OIL-FIRED CENTRAL HEATING APPARATUS

Contractors wishing to submit a firm price TENDER for the above should forward their names, from which a panel will be chosen and provided with Tender documents.

The work, which is to be completed by the beginning of the next heating season, consists of the PROVISION OF OIL-FIRED CENTRAL HEATING APPARATUS, estimated cost £2950.

Applications to reach the undersigned not later than 7th May, 1960.

H. CONOLLY, C.B.E., F.R.I.B.A.,
County Hall, County Architect.
Chelmsford. E9603

EDUCATIONAL

UNIVERSITY OF LONDON KING'S COLLEGE

TUTORIAL STUDENTSHIP IN MECHANICAL ENGINEERING

A TUTORIAL STUDENTSHIP is offered in the Department of Mechanical Engineering. The value is £425 a year, with free tuition, from 1st October, 1960. Applicants must be graduates or about to graduate, and will be required to read for a higher degree, and to give a limited amount of assistance by demonstrating.

The successful applicant will be expected to take part, under supervision, in research in Refrigeration.

Particulars and forms from the Registrar, King's College, Strand, W.C.2, whom completed applications should reach not later than May 20. E9584 E

A.M.I.MECH.E., B.Sc., City and Guilds, &c. Guarantee Postal Courses for all Exams. and Technical Divisions from Elementary to Degree standard including Automation Techniques. Approximately 95 per cent. successes. 148-page prospectus free, on request.—B.I.E.T. (Dept. 22), 29, Wright's Lane, London W.8 E114 E

EDUCATIONAL

ADMIRALTY

ROYAL CORPS OF NAVAL CONSTRUCTORS

SCHOOLS ENTRY

A competition for entry into the Royal Corps of Naval Constructors will be held in July, 1960.

2. Accepted candidates will be established as probationers in the Royal Corps of Naval Constructors and will undergo a two-year course of training at the R.N. Engineering College, Manadon, and in H.M. Dockyard, Devonport, followed by a three-year course at the R.N. College, Greenwich.

3. Candidates must be aged between 17 years 6 months and 19 years 6 months, inclusive at 1st September, 1960.

4. Candidates with the General Certificate of Education will be required to have passed at Advanced Level in at least Pure Mathematics, Applied Mathematics, and Physics taken on the same occasion, and at least Ordinary Level passes in English and a language other than English.

5. Candidates with the Scottish Leaving Certificate will be required to have Higher grade passes in Science (to include Physics), Mathematics, at least two additional mathematical subjects (one of which must be Dynamics), and at least lower grade passes in English and a language other than English. Passes to be gained at not more than two sittings of the Scottish Leaving Certificate examination.

6. Candidates with the Northern Ireland Grammar School Senior Certificate will be required to have passes at Advanced Level in Mathematics (General Course, Pure Mathematics, Applied Mathematics) and Physics—taken on the same occasion ; and at least Ordinary Level passes in English and a language other than English.

7. Applications will be considered from candidates who sit these examinations in 1960.

8. The work of the R.C.N.C. covers all aspects of design, construction and repair to H.M. Ships. Members undertake to serve wherever required at Admiralty headquarters, Outports in the United Kingdom and at Royal Dockyards at home and abroad.

9. The starting pay of a probationer at age 18 will be £545. A deduction of £75 is made when living in at the R.N. Engineering College, Manadon, or at the R.N. College, Greenwich. The successful probationer can expect an appointment as Assistant Constructor at age 23 or 24 with a starting salary of not less than £910 and £940 respectively. Promotion to Constructor normally takes place at about age 30 with a salary which may be expected to be not less than £1515, rising in nine years to not less than £2255. Promotion to higher ranks is by selection.

10. Full particulars may be obtained from the Secretary of the Admiralty, Civil Establishments Branch II(88), Empire Hotel, Bath, quoting reference number 6015, to whom final application must be submitted by 16th May, 1960. E8783 E

COLLEGE OF AERONAUTICS

DEPARTMENT OF AIRCRAFT ECONOMICS AND PRODUCTION

A SHORT COURSE ON
AUTOMATIC PRODUCTION AND CONTROL

will be held at the College from
MONDAY, 11th JULY, to FRIDAY, 22nd JULY, 1960

The Course is intended to serve as an introduction to the subject of Automatic Control as applied to machine tools. Topics to be covered include basic control theory, components and actuators, and complete control systems ; a large part of the Course will be devoted to experimental work on components and machine tools.

Fees for the Course are £60 inclusive of full board residence.

Further details and forms of enrolment may be obtained on application to the Warden, The College of Aeronautics, Cranfield, Bletchley, Bucks. E9377 E

BATTERSEA COLLEGE OF TECHNOLOGY

ELECTRICAL ENGINEERING DEPARTMENT

The fourth full-time postgraduate course in Control Engineering will commence on 3rd October, 1960.

The Department of Scientific and Industrial Research has accepted this course as suitable for the tenure of its Advanced Course Studentships.

Enquiries to : The Secretary (Automatic Control), Battersea College of Technology, Battersea Park Road, London, S.W.11. E9582 E

UNIVERSITY OF LONDON KING'S COLLEGE

SHELL STUDENTSHIPS IN CHEMICAL ENGINEERING

Value £375 each, plus tuition fees. May be held for the one-year postgraduate course for the College Diploma in Chemical Engineering, or for the first year (with possible renewal) of higher degree work.

Applications are invited from graduates in Chemistry or Engineering. Forms must be obtained from the Registrar, King's College, Strand, London, W.C.2, and must reach him completed by May 26th, 1960. E9583 E

SITUATIONS VACANT

APPLICANTS ARE ADVISED TO SEND COPIES NOT ORIGINALS OF THEIR TESTIMONIALS UNLESS OTHERWISE REQUESTED.

CHIEF DRAUGHTSMAN.—A leading Company in the Roadstone Industry requires a Chief Draughtsman to take charge of the drawing office. The work involves major development schemes, and applicants should have experience in the roadstone, quarrying or allied industries.—Applications containing full details should be sent to BOX No. E9623, "The Engineer." A

SITUATIONS VACANT

ASSISTANT CIVIL ENGINEER

Applications are invited from Chartered Civil Engineers with from 2-5 years' experience, preferably with contractors, for the above appointment.

The successful applicant will be required for work either on site or at a branch office in South Western England.

Salary will be in accordance with qualifications and experience, but not less than £1000 per annum.

Applications, stating age, qualifications and experience, should be sent to :—

Gray, Conoley & Co., Ltd.,
Stephenson Street,
London, E.16.

E2816 A

CHIEF MECHANICAL ENGINEER, age 30-45. Applicant must have served an engineering apprenticeship and should hold the H.N.C. in Mechanical Engineering or equivalent. Will be required, with 3 or 4 assistants, to be responsible for installation and maintenance of mixing, processing and automatic packaging machinery in food factory, N. London.—Write full details of experience to BOX No. E9615, "The Engineer." A

CIVIL SERVICES AND MECHANICAL DESIGN DRAUGHTSMEN

required by

BRITISH NYLON SPINNERS LIMITED

Applications are invited from men in the age range 26-45, with several years' experience of design work. In addition to experience, candidates must possess at least an O.N.C. or equivalent qualification but Higher National Certificate is preferred. Good starting salaries are offered and there is ample scope for advancement on a basis of merit. Married applicants can rent unfurnished houses or flats in the area and assistance will be given with removal expenses.

Please apply in writing, giving full particulars, to :—

THE PERSONNEL MANAGER,
BRITISH NYLON SPINNERS LIMITED,
PONTYPOOL, MON.

E9634 A

DESIGN ENGINEERS AND DESIGNER DRAUGHTSMEN

with up to eight year's experience in design of Reinforced Concrete and Steel Structures in connection with Power Stations, Tunnels and Railway work. Apply ; giving details of experience to :
SIR WILLIAM HALCROW & PARTNERS,
ALLIANCE HOUSE, CAXTON STREET,
LONDON, S.W.1.

E9599 A

ENGINEER-DRAUGHTSMAN with light press tool experience on mass production of aluminium foil products. Time served man with design experience and higher technical education at least to H.N.C. Age preferably 30 to 45. Based in London area.—Applications, with full particulars of education, training and experience, with salary expected, to BOX No. E2813, "The Engineer." A

ENGINEERING ASSISTANTS experienced in the design of Reinforced Concrete Bridges and other structures, and capable of supervising Drawing Office Staff, are required to fill vacancies in both the Senior Engineering Assistant and Group "C" posts in the salary ranges £1045-£1095 and £990-£1034 respectively. Superannuation Fund : Reduced rates of travel and other concessions ; 5-day week.—Applications, giving qualifications, age, and experience, to : Chief Civil Engineer, British Railways, Western Region, Paddington Station, London, W.2. E9586 A

ENGINEERING, PHYSICS AND SCIENCE GRADUATES OR EQUIVALENTS required for new appointments involving research, design and development work on :

(1) Machining processes ; initially work will be concerned with the appraisal of new machining developments.
(2) Mechanical engineering equipment including special machine tools, presses, mechanisms, test rigs, etc.

Successful candidates will be expected to take complete responsibility for projects from conception to completion. Capacity for creative thinking and initiative are important. The conditions of employment are attractive. Superannuation scheme. Removal expenses paid.—Send full details in confidence to the Secretary (R.671), Production Engineering Research Association, Melton Mowbray, Leics. E9576 A

EXPERIMENTAL OFFICER required at the National Institute of Agricultural Engineering to work, in co-operation with the Dept. of Hop Research Wye College (University of London), on engineering problems connected with the mechanisation of hops and hops drying. Applicants should possess degree in engineering, H.N.C. or equivalent qualifications, and have experience of research work. Minimum age 28 years, superannuation. Salary scale £954-£1166.—Application forms from the Secretary, N.I.A.E., Silsoe, Beds. E9609 A

INSTRUMENT ENGINEERS.—Simon-Carves, Limited, require Instrument Engineers for employment in U.K. and overseas. Experience of instrumentation of chemical/refinery installations desirable. Men with works training and holding O.N.C. or H.N.C. are preferred. Please forward full details of age, experience and qualifications and quoting Ref. SC.36, to Contract Labour Department, Simon-Carves, Limited, Stockport. E9499 A

SITUATIONS VACANT

FACTORY MANAGEMENT EXECUTIVE

Gentlemen trained and experienced in the maintenance of large Factories and Labour Control, will shortly be required as ASSISTANT to Works Superintendent controlling group of factories in North of England city.

Candidates for this position, who should be in age group 33 to 40, are asked to include in their applications full details of training, past experience also of positions held, and should at present be in receipt of not less than £1500 per annum.

The position is superannuable.

Letters received will be treated with the utmost confidence.—Write BOX No. E9581, "The Engineer." A

FIRTH CLEVELAND STEEL STRIP LTD., Tipton, Staffs, a Member of the Firth Cleveland Group, require a MECHANICAL ENGINEER to take charge of Development and to understudy the Chief Engineer. The position is concerned with the applications of the various technologies encountered in mechanical electrical and chemical engineering, and the heat treatment of steel. Applicants will not be expected to have knowledge of all these, but must be capable of absorbing the knowledge where necessary. Prospects of the post offered are good and salary will be commensurate with the requirements indicated. All applications will be considered, and should be addressed to : the Works Director, Firth Cleveland Steel Strip Limited, Locarno Road, Tipton, Staffs. E9641 A

INDUSTRIAL FURNACE CONSTRUCTION COMPANY, engaged principally in Iron and Steel Industry on construction of Open Hearth Steel Furnaces, Soaking Pits, Rotary and Annealing Furnaces, &c., and Blast Furnace linings, require the following staff.

SITE ENGINEERS. Age 30 to 40 years.
JUNIOR SITE ENGINEERS. Age 23 to 30 years.

Applicants should preferably be qualified engineers with iron and steelworks experience, but Engineers with sound practical experience will be considered. These are permanent appointments with participation in pension scheme after probationary period. Salary commensurate with qualifications and experience, plus bonus. Applications, giving personal details, qualifications and experience.—BOX No. E9639, "The Engineer." A

JUNIOR ENGINEER required with view to early promotion to area engineer in charge of large modern fleet of mobile cranes. Pref. qual. H.N.C. Sound apprenticeship in general engineering or transport and some administrative and commercial experience. Location near Sheffield. Progressive superannuated post commencing £750 approx. p.a.—BOX No. E9614, "The Engineer." A

LONDON-KENSINGTON MECHANICAL POWER TRANSMISSION ENGINEERS require TECHNICAL ASSISTANT, age 21 to 25, to H.N.C. or G.M.I.Mech.E. standards. Duties cover the study of a wide variety of power transmission and motorisation problems from data supplied by customers and sales force. Selected applicant will undergo comprehensive training course. Expanding firm offers excellent opportunities for keen and energetic applicant. Pension scheme.—Reply BOX No. E2815, "The Engineer." A

MECHANICAL ENGINEER—temporary—required by Iron Ore Mining Company for one tour of approximately 15 months duty in BRITISH WEST AFRICA to assist in supervision of the contract for the installation of Plant and Machinery, including electrics, in an ore concentrating plant. Previous experience contract supervision essential. Salary £1900 per annum plus bonus ; plus, for married man, marriage allowance at the rate of £10 per month and children's allowance at the rate of £5 per month for each child under 18, but bachelor accommodation only available. Dependants Income Scheme and free Life Assurance. Return passage paid. Initial kit allowance. Free furnished single accommodation and medical attention.—Write, giving full details of experience, stating age, married or single to SIERRA LEONE DEVELOPMENT CO. LTD., Dept. M.E.2, City Gate House, Finsbury Square, London, E.C.2. E9612 A

REFRIGERATION ENGINEER required as deputy to Chief Engineer for large London cold store. Must be fully qualified in refrigeration, experienced in handling labour, and able to supervise major installation work. Good salary, pension scheme and excellent prospects.—Full details to BOX No. E2812, "The Engineer." A

REGENT OIL CO. LTD.

invite applications from qualified Civil Engineers to fill the position of

EXECUTIVE (PROJECT) ENGINEER

in central office, London. Applicants should be 30-40 years of age, with either a Degree in Civil Engineering or Corporate Membership of Institution of Civil Engineers. Must be able to produce confirmation of previous responsibility for projects. Applicants should write, giving details of training and experience, to :

Personnel Officer,
Regent Oil Co. Ltd.,
117, Park Street, London, W.1.

E9633 A

SALES REPRESENTATIVE with proven sales record and a sound technical background in Commercial Refrigeration—preferably with Air Conditioning experience, required by distributors of American Manufactured Air Conditioning Units. This is a new appointment with excellent prospects. The successful applicant will receive a generous salary plus expenses and be based in N. London. A car will be provided if required.—Reply BOX No. E2819, "The Engineer." A

SENIOR ENGINEER with knowledge and previous experience in the design of evaporative water coolers for industrial applications, required by progressive company, located 15 miles south of London. Holiday arrangements accepted.—Write, stating age, qualifications, previous experience, salary required to BOX No. E9570, "The Engineer." A

SITUATIONS VACANT

STEELWORK DETAILING DRAUGHTSMEN required for Westminster office, experienced in all types of structures, with the minimum of supervision. Write, stating age and salary desired.—BOX No. E2818, "The Engineer." A

STRUCTURAL STEELWORK DESIGNER required, conversant with L.C.C. by-laws and B.S.S. 449. Experience essential in all types of steel structures and portal frames. Westminster office. Write, stating age and salary desired.—BOX No. E2817, "The Engineer." A

WANTED, FIRST-CLASS SENIOR DESIGN DRAUGHTSMAN for firm of General Engineers in Bristol. Good knowledge of general engineering, with particular reference to pressure vessels and stainless steel fabrication. This will be a well-paid position for the top-class man.—BOX No. E164, "The Engineer." A

YOUNG EXPERIMENTAL ENGINEER DRAUGHTSMAN wanted, to join small team working on shoe production devices. Qualifications: Inventiveness and design ability essential. Preference will be given to applicants with H.N.C. or studying for it. (One day per week will be allowed for completion of approved studies.) The starting salary and future prospects will attract young men of ability, and previous experience, even if not directly relevant, will be taken fully into account. Further details on request.—Applications to: Director, BRITISH BOOT, SHOE & ALLIED TRADES RESEARCH ASSOCIATION, Satra House, Rockingham Road, Kettering, Northants. E9643 A

THE FAIRFIELD SHIPBUILDING AND ENGINEERING COMPANY LIMITED
GOVAN, GLASGOW

Invite applications for the following position:

HEAD FOREMAN

to take charge of Gearing Department. Applicants should have a wide experience in the production of High Accuracy Marine Reduction Gearing.

Applications for the above position will be treated as confidential, and should be addressed to the Company stating age, qualifications and experience.

No references are required in the first instance.

The successful applicant will be expected to join the Company's pension scheme.

E9496 A

OVERSEAS APPOINTMENTS

SIMON-CARVES, LIMITED,

require

MECHANICAL ENGINEERS

FOR OVERSEAS CONTRACTS

Applications are invited from men between 30 and 40 years of age who have experience in the erection and installation of electrical and heavy mechanical engineering plant, including H.P. compressors, pipelines and vessels. A.M.I.Mech.E. or similar qualification desirable.

Applications, quoting Ref. No. 31 with details of age, experience and qualifications, should be forwarded to Contract Labour Dept., Simon-Carves, Ltd., Cheadle Heath, Stockport.

E9500 A

SITUATIONS VACANT

'ENGLISH ELECTRIC'

offers opportunities to

MECHANICAL, CHEMICAL & ELECTRICAL ENGINEERS & PHYSICISTS

These opportunities exist at all levels of seniority and we will be especially pleased to hear from men who have been successful in their initial design and development work and who feel that either their progress is restricted in their present position or they would welcome an opportunity of widening their experience in a new field. If you are interested in investigating these opportunities that we may be able to offer you, why not write to the address below, giving details of your previous experience, age, qualifications and salary. Correspondence will be treated in strictest confidence.

A few of the vacancies are indicated below but many others exist and the Company is always prepared to accommodate promising men in their organisation. We welcome enquiries.

ELECTRICAL & MECHANICAL ENGINEERS

For development investigations on reactor equipment with special reference to control gear and fuelling and fuel handling systems, with associated electrical and data processing equipment. These investigations would involve handling large items of plant operating at high temperatures and pressure.

These appointments are for men of Degree calibre with post-graduate experience, preferably on development work; although applications from ex-apprentices with H.N.C. would be considered.

DESIGN ENGINEERS

Mechanical, civil or chemical engineers who are interested in design problems associated with pressure vessels and structures, heat transfer and fluid mechanics (as applied to the cooling of large vessels), vibrations, bearing friction or the determination of temperature distribution in plant, would find interest in this sphere.

The nature of these problems would require men with an Honours Degree (or its equivalent) and the ability to think clearly.

DESIGNERS

To be responsible for the design of apparatus for investigating problems of heat transfer, air flow and the performance of mechanical components of reactors.

A Degree or H.N.C., together with workshop experience and two to three years' design experience in the field of medium mechanical engineering is essential. A knowledge of pressure vessels and pipework could be an advantage but the main requirement is for a man with flexibility and originality of approach who is prepared to follow a design through to its installation and commissioning in a laboratory.

ENGINEERS, PHYSICISTS & MATHEMATICIANS

To be responsible for the examination of problems connected with nuclear reactor fuel element design and development, and for the design of new fuel elements.

A good Honours Degree in the appropriate subject is essential and the experience required may be classified as follows:

1. Interest in the creep deflection of structures at high temperature, preferably with a background of the mechanics of plastic solids, or of the plastic theory of structures.
2. Experience in stress analysis with a good mathematical background.
3. Experience in the engineering applications of physics.

ELECTRICAL ENGINEERS

Interested in design and contract engineering, especially in connection with reactor auxiliary plant and control systems and reactor automatic control systems. The work involves responsibility for schemes from design initiation to site completion and a small amount of travelling may be involved in connection with technical liaison with outside sub-contractors and other works of the Company.

Experience is necessary in one or more of the following fields: relay and contactor control systems, safety interlocking systems, telecommunication circuiting, automatic control system analysis and servo systems and components.

It is expected that the successful applicant will hold a Degree or H.N.C. but capability and achievement are the primary considerations.

GAS CIRCUIT ENGINEERS

To conceive the design of gas circuits and study the economic selection of components, circulator drive systems and methods of gas flow. The duties could also cover analysis of local performance specification of engineering features and the behaviour of the system under fault conditions apart from general thermodynamic and aerodynamic problems.

These positions require men of Honours Degree calibre and experience in turbine or axial compression, thermodynamics and aerodynamics would be an advantage.

MECHANICAL & CHEMICAL ENGINEERS & PHYSICISTS

To perform theoretical and experimental investigations associated with problems of heat transfer and gas flow in nuclear reactors. These positions require a Degree in Chemical or Mechanical Engineering or Physics, and experience or interest in heat transfer or aerodynamic research and development work.

There are also positions available for O.N.C. or H.N.C. men with similar interests or experience in the commissioning or performance testing of power station or chemical plant.

Please address correspondence and enquiries to the
Technical Staff Officer, C.P.S., Marconi House, Strand, W.C.2.,
quoting reference E1816G.

E9618 A

Development Engineer

aged 30/40, required for a substantial and rapidly growing concern in the heavy chemical field located in the North of England.

A good Engineering Degree is essential, together with experience in experimental and development work in medium engineering associated with chemical plants. A good knowledge of handling of corrosive liquids and gases and thermodynamics is also required. Those unable to satisfy these requirements need not apply.

The successful candidate will be expected to deal with specific technical problems and will be required to suggest and study new developments and practices.

This is a responsible position for which a commensurate salary will be paid.

A sound non-contributory Life Assurance and Pension Scheme is in operation. Bonus Scheme. Housing assistance to married men. 5-day week.

Applications giving full details, i.e. age, education, and experience should be addressed to BOX No. E183, "The Engineer."

A

GKN

GROUP RESEARCH LABORATORY, WOLVERHAMPTON

The Liaison and Information Division of this Laboratory, which serves a Group of some eighty companies engaged in steel making and general engineering, has vacancies for:

L1.1 A TECHNICAL WRITER who will be responsible for the production of a technical journal and for writing and producing a six-monthly progress report on the work of the Laboratory. Some technical knowledge and the ability to present technical information in an interesting and understandable form are required.

L1.2 A LIAISON OFFICER who will be responsible for the technical secretarial work of a number of committees, both in the Laboratory and in the Group. He will also be responsible for general liaison work, including the entertainment of visitors to the Laboratory.

Applicants for both these posts should preferably be under 30. Applications, quoting reference and giving details of age, qualifications, experience, etc., should be addressed to:

The Recruitment Officer,
G.K.N. Group Research Laboratory,
Birmingham New Road, Lanesfield,
Wolverhampton.

E9598 A

Classified Advts. continued on page 104

SITUATIONS VACANT

M.T.D. (MANGULA) LIMITED

require an

ASSISTANT MECHANICAL ENGINEER

for their Copper Mines at Mangula, Southern Rhodesia. The successful candidate will be aged 35 or under, will have served a recognised apprenticeship in Mechanical Engineering and subsequently will have had at least three years' practical experience. He will be a Chartered Mechanical Engineer or possess the Higher National Certificate (Mechanical). Mining experience will be an advantage.

Salary : £1680-£1800 p.a., plus C.O.L.A., plus passage and expenses, plus house at nominal rental, etc.

Application form and further particulars from Merz and McLellan, Milburn, Esher, Surrey. E9637 A

SITUATIONS VACANT

MECHANICAL ENGINEER

Countrywide commercial engineering organisation with headquarters in the North of England seeks to augment its Headquarters engineering staff by the addition of a mechanical engineer with an interest in

NUCLEAR ENGINEERING AND ELECTRONICS.

Further training will be arranged if necessary. Position is pensionable. Salary by arrangement.

Applicants, who should be aged about 30, should have reached Degree standard and should give full details of their careers and qualifications in their letter of application.—BOX No. E9595, "The Engineer." A

SITUATIONS VACANT

TECHNICAL WRITER

Required by the Publicity Department of

BABCOCK & WILCOX, LTD.,
LONDON

(makers of nuclear power plant, steam-raising equipment, materials-handling plant, cranes, etc.)

for the preparation of technical sales publication texts, press articles, exhibition display texts, etc. Must, above all, have the ability to write *good, concise English*, a flair for attractive presentation and experience in the extraction and logical assembly of information on engineering and industrial subjects.

Interesting work covering a wide field of subject matter, and with a Company having world-wide associations.

Preference is for a younger man, under 35 years. Graduates with some engineering experience and with a liking and ability for technical writing would be considered.

PENSION SCHEME. CANTEEN FACILITIES.

Salary according to qualifications and experience.

Apply : Manager, Publicity Department, Babcock & Wilcox, Ltd., Babcock House, 209, Euston Road, LONDON, N.W.1. E9610 A

SITUATIONS VACANT

GENERAL MANAGER

required for small but developing Company of

GENERAL MECHANICAL HANDLING ENGINEERS

on outskirts of Birmingham.

Applicants should have sound technical background, proved administrative ability and knowledge of production. Good commencing salary and excellent prospects.

Apply BOX No. E9624, "THE ENGINEER." A

ENGINEER FOR INTERNATIONAL INVESTMENT INSTITUTION

WASHINGTON, D.C., U.S.A.

The basic requirements for this position are a Degree in Engineering from a University or professional institution ; some years in industry ; and a successful record in engineering or industrial consultancy.

The work involves the technical analysis of a wide variety of industrial projects in all parts of the world either from written presentations or by on-the-spot investigations. An appreciation of marketing and the ability to make market analyses are also essential.

Applicants (aged about 35/45) should have a broad outlook and experience ; assistance from specialists in any particular field outside the competency of the engineering staff is available as required. A critical and analytical approach with the ability to write clear and concise reports are essential requirements. Fluent English is essential and other languages desirable.

The successful applicant will be stationed in Washington but will be expected to make short visits overseas from time to time. All removal expenses for the applicant and his family will be paid and there are generous home leave privileges. The position is permanent and offers a most interesting variety of work ; salary will be commensurate with qualifications and experience.

Applicants should send in confidence and in English a short but comprehensive statement about their careers and background to BOX No. E9597, "The Engineer." A

BRITISH OXYGEN GASES LIMITED

DEVELOPMENT ENGINEER

British Oxygen Gases have a vacancy in their Development Group Electrical Section for a Development Engineer. Candidates should be at least 28 years of age and have a B.Sc. degree or equivalent qualifications in Electrical Engineering. Candidates should also have at least 5 years' experience in one or more of the following fields :

1. Electronic Circuit design.
2. Automatic Control of Servo Equipment of the type applied to machine tools.
3. Transistor Circuit Technique.

The successful candidate will be required to handle a particular project with a minimum of supervision.

Write, stating full details to the

PERSONNEL MANAGER, BRITISH OXYGEN GASES LIMITED, SPENCER HOUSE, ST. JAMES'S PLACE, LONDON, S.W.1.

E9644 A

THE MOTHERWELL BRIDGE & ENGINEERING COMPANY LTD.

DESIGN ENGINEERS

ASSISTANT CHIEF DESIGNER (REF. DD-1)

Applications are invited for the above post from honours graduates in Mechanical Engineering who have had several years' experience in the design of Pressure Vessels, Chemical Plant and refinery equipment, and, in addition, design experience in structural steelwork.

Applicants should be between 30 and 35 years of age and be corporate members of the Institution of Mechanical or Structural Engineers.

Duties will include the execution and responsibility for checking of designs. Applicants should have a good bearing and pleasant manner and be willing to travel, as the scope of the position will extend to meeting representatives of other companies on technical matters.

An attractive commencing salary is offered and will be based upon the qualifications and experience of the successful applicant.

DESIGN ENGINEER (REF. DD-2)

Applications are invited from Engineers holding a degree or equivalent qualification in Mechanical or Structural Engineering for specialised design work on Gas, Chemical and Oil Refinery Plant and Equipment.

Applications from Engineers graduating this year will be considered.

The position carries responsibility for the execution of original designs and offers a wide scope for engineers wishing to specialise in this type of equipment. Commencing salary will be not less than £800 p.a., but would be increased above this depending on age and experience.

Both posts are pensionable and the company offers excellent Canteen and recreational facilities. Apply, quoting reference number and giving full details of qualifications and experience, to The Motherwell Bridge & Engineering Co. Ltd., P.O. Box 4, Motherwell.

E9596 A

ATOMIC ENERGY ESTABLISHMENT, WINFRITH

PROFESSIONALLY QUALIFIED ENGINEERS

are required to work on a shift basis in the control of operation and maintenance. Experience in the following fields is essential :

(*a*) Control of sub-stations and power supplies.
(*b*) Operation and maintenance of boiler and machinery plant, including pumping, heating, and ventilating equipment.
(*c*) Maintenance of Site Services, including effluent disposal.

Duties will also involve supporting the Health Physics Organisation, which will require an intensive training course in radiation hazards and their control. Managerial ability is required, and experience of damage control duties or of work in radioactive areas would be an advantage.

Salary : £1370-£1825 per annum.

Housing and superannuation schemes.

Send POSTCARD for application form and details to :

Personnel Branch (W.275/25),
U.K.A.E.A.,
A.E.E., Winfrith, Dorchester, Dorset.

Not later than 20th May, 1960.

E9591 A

DESIGN ENGINEER

required by

THE ATOMIC WEAPONS RESEARCH ESTABLISHMENT, ALDERMASTON, BERKSHIRE.

To be responsible for design and development of a wide range of light mechanical equipment with a bias towards precision instrumentation.

Applicants should be Corporate members of the Institution of Mechanical Engineers or have equivalent qualifications. They should have had several years' design office experience. A sound knowledge of elementary physics would be an advantage.

SALARY :
Within the range £860-£1825, according to age, qualifications and experience.

Contributory Superannuation Scheme. A house, or substantial assistance with house purchase, will become available for married officers living beyond daily travelling distance.

POSTCARD (or letter) for application form to the Senior Recruitment Officer at above address. Please quote ref. A.2533/25.

E9638 A

SITUATIONS VACANT

ENGINEERS FOR FOOD RESEARCH

UNILEVER offers young Qualified Engineers the opportunity of joining the expanding Research and Development activities at the Company's Food Research Department.

New techniques of food processing require imaginative investigations in Process Design and in Mechanical Design of special equipment. This is comparatively new work for Mechanical Engineers and provides a challenge for those with initiative to influence the future pattern of Food Processing.

The Department includes a new Pilot Processing Wing and is situated in a pleasant country estate 10 miles north of Bedford.

Please write to The Staff Officer (FRR/32) at Food Research Dept., Colworth House, Sharnbrook, Bedford.

E9592 A

W. H. ALLEN SONS & COMPANY, LTD.,
require

AN ENGINEER

for their new

CENTRAL RESEARCH DEPARTMENT

A new Central Research Department has been formed by the Company and a qualified Engineer is required to help build up a team. The work will cover steam and gas turbines, pumps, gearing, etc.

A good academic training (First Class Honours Degree or equivalent) is essential. Some industrial experience is desirable but not essential.

The Company offers excellent conditions of employment, a Contributory Pension and Life Assurance scheme and comprehensive recreational and welfare amenities. Assistance is also given towards removal expenses, etc.

Applications, giving details of qualifications and experience, should be made in writing to :—

The Personnel Manager (Ref. 1002/3),
Queens Engineering Works,
BEDFORD.

E9585 A

SITUATIONS WANTED

CHIEF ENGINEERING BUYER, with energy and drive, 36, single, top references. A Senior and responsible post only will be considered with a Company who needs a well-informed man with 18 years' top level experience. Advertiser is an old Etonian, and former Army Contracts Adviser.—BOX No. E2820, "The Engineer." B

SUB-CONTRACTING

KELLERING AND CAM PROFILING capacity up to 8ft. by 6ft. or 6ft. diameter.—ARMYTAGE BROS. (KNOTTINGLEY), Ltd., The Foundry, Knottingley, Yorkshire (Telephone : Knottingley 2743/4). E116 MW

BUSINESS OPPORTUNITIES

REMPLOY SPONSORSHIP SCHEME

Send for details which show an attractive proposition to manufacturers.

Write to the Managing Director, Remploy, Ltd., 25-28, Buckingham Gate, S.W.1, or telephone VICtoria 6621 (12 lines).

E9064 D

A BARGAIN. £25 complete. BRAND NEW READY-MADE CO. REGNS. Guaranteed no trading (ENGLAND OR SCOTLAND)—all trades available NOW, including Engineering ; Electrical Engineering ; Motor Engineering ; Garage ; Machinery ; Metal ; Haulage ; Hire Purchase ; Investment ; Property (specially prepared for each trade).—BUSINESS ECONOMY CO. REGNS., LTD., Dept. T/16, 156, Strand, London, W.C.2 (Tem. 8377/2294), for English companies, and to 19, Walker Street, Edinburgh, 3 (Cal. 1167/8/9), for Scottish Companies. Read "ADVANTAGES OF TRADING AS A LIMITED COMPANY" (3s. post free) ; Limited Co. may save you tax. We have seven-day Co. Regn. service with your own choice of name. £21 complete, plus stamp duties. E182 D

DRAWING & DESIGN SERVICE

SENIOR DESIGNER requires private work. Southern Area, offers undertaking of Schemes, Layouts and details of Mechanical Handling Equipment, Steelwork, Plant Layout. Good references. Site surveys on weekends.—BOX No. E2821, "The Engineer." S

BUSINESSES & PREMISES

EST. ERS&K 1855.

FOR SALE BY PRIVATE TREATY WITH VACANT POSSESSION

EXTENSIVE SINGLE-STOREY WORKS PREMISES

WIDNES LANCASHIRE

19 ACRE FREEHOLD SITE

160,000 SQ. FT. FLOOR SPACE

MOST SUITABLE FOR CHEMICAL, ENGINEERING AND TIMBER TRADES.

INTERNAL RAILWAY AND PRIVATE SIDING ACCOMMODATION.

Widnes is situated in a highly industrialised area with reasonable access to Warrington, Liverpool and Manchester.

Apply,

EDWARD RUSHTON SON & KENYON

Industrial Estates Department.

York House,
12, York Street,
Manchester, 2.
Tel.: CENtral 1937.

50/51, Broad Street Avenue,
Blomfield Street,
London, E.C.2.
Tel.: LONdon Wall 4601.

E9628 L

AGENCIES

MANUFACTURERS AGENTS required to sell special range of Ball-type Valves which are already in general demand, covering (a) South Eastern Counties ; (b) Eastern Counties.—BOX No. E9601, "The Engineer." D

SOUTH WALES ENGINEERING COMPANY with large amount of manufacturing capacity available, require AGENTS to introduce contract or sub-contract work, on a commission only basis.—BOX No. E2814, "The Engineer." D

FOR HIRE

LATTICE STEEL ERECTION MASTS (light and heavy), 30ft. to 150ft. high, for immediate hire.—Bellman's, 21, Hobart House, Grosvenor Place, S.W.1. E103 K

MISCELLANEOUS

LUSOL

KILLS RUST AND LUBRICATES

LUSOL The Rust Solvent is invaluable for Dismantling, Repairing and Overhauling Engineering Equipment. Obtainable from your usual Supplier. Enquiries to the manufacturers :—

The Great Eastern Oil Co., Ltd.,
372, Scotland Street, Glasgow. Tel. : South 2207
E184 I

MACHINERY Etc. WANTED

WANTED.—3-high Rolling Mills, Rolls approx. 16in. diameter. For hot rolling billets up to maximum 6in. square.—Full details, etc., to BOX No. E9621, "The Engineer." F

URGENTLY REQUIRED TO PURCHASE. 6-ton Coles, Neals or Jones Mobile Crane, on pneumatics.—Full details BOX No. E9627, "The Engineer." F

URGENTLY REQUIRED TO PURCHASE. 7/10-ton, 2-motor type, Electric Derrick Crane.—Full details BOX No. E107, "The Engineer." F

FOR SALE

600

ELECTRICALLY DRIVEN COMPRESSOR SETS FOR USE ON 400/440 VOLTS, 3-PHASE 50 CYCLES SUPPLY

1000 c.f.m. ALLEY & MACLELLAN, 100 p.s.i.
Two 750 c.f.m. ALLEY & MACLELLAN, 100 p.s.i.
Two 688/674 c.f.m. C.P.T., 100/125 p.s.i.
625 c.f.m. ALLEY & MACLELLAN, 100 p.s.i.
600 c.f.m. BROOM & WADE, 100 p.s.i.
376 c.f.m. BELLISS & MORCOM, 125 p.s.i.
320 c.f.m. CLIMAX ENGINEERING, 100 p.s.i.
305 c.f.m. HOLMAN, 100 p.s.i.
300 c.f.m. ALLEY & MACLELLAN, 100 p.s.i.
169 c.f.m. INGERSOLL RAND, 100 p.s.i.
150 c.f.m. REAVELL, 100 p.s.i.
130 c.f.m. BROOM & WADE, 100 p.s.i.
100 c.f.m. REAVELL, 120 p.s.i.
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GEORGE COHEN,
SONS AND CO. LTD.
WOOD LANE, LONDON, W.12.
Tel.: Shepherds Bush 2070 ; and
STANNINGLEY, Nr. LEEDS.
Tel.: Pudsey 2241. E201 G

FOR SALE

FRED WATKINS (ENGINEERING) LTD.

STEAM BOILERS.—Cochrane Vertical (New), 8ft. 6in., 8ft., 7ft. 6in., 7ft. and 6ft. in dia., 100/150 lb. w.p ; reconditioned 8ft. 6in. down to 3ft. dia.; Economic 4ft. to 11ft. 6in. dia., including new 7ft. and 8ft. dia., 150, 180 and 200 lb. w.p.; 300 reconditioned Vertical Crosstube, all sizes.

AIR COMPRESSORS.—Two Belliss & Morcom 2500 c.f.m., 100 p.s.i., 550 h.p. motors ; also Broomwade 500, 400, 300, 200 and 130 c.f.m., all motorised ; and several others of various makes and capacities.

200 AIR RECEIVERS, stocked up to 9ft. dia., 100 to 500 lb. pressure.

ELECTRIC MOTORS.—150 Totally Enclosed and Flameproof Motors up to 200 h.p.

MOBILE ROAD CRANES.—10-ton Lorain lorry, mounted 30ft.–70ft. extendible jib ; 10-ton 33 R.B. track mounted, 40ft. jib ; 8½-ton Ransomes Diesel/Electric, 21ft. jib. 6-ton Coles Diesel/Electric, pneumatics, new 1948 (2) ; 6-ton Coles Diesel/Electric, solids ; 4-ton Coles Diesel/Electric, solids, 1945 ; 4-ton Jones KL44, diesel, 1950 ; 3-ton Jones "Super 40" diesel, pneumatics (3)

OVERHEAD CRANES.—20-ton Vaughan, 42ft. 3in. span, 6-ton auxiliary, cab control (5) ; 20-ton King, 42ft. 3in. span, 400/3/50 ; 15-ton Booth, 37ft. span, 400/3/50 ; Wharton 7½-ton, 25ft. span, 400/3/50 ; 5-ton Henderson, 24ft. 7in. span, 1946 ; 5-ton Morris, 58ft. span, hand-operated ; 5-ton King, 29ft. 3in. span, power hoist, hand travel ; 5-ton Morris, 28ft. 6in. span, power hoist, hand travel ; 4-ton Morris, 19ft. span, 220V. d.c. (3) ; 2-ton Vaughan, 27ft. 6in. span, 2-motor ; majority of the above are unused.

DERRICK CRANES.—7-ton Anderson Grice, 100ft. jib, electric ; 7-ton Rushworth, hand, 30ft. jib ; 1½-ton Anderson Grice, hand, 40ft. jib ; 5-ton Butters Grabbing, 80ft. jib, electric.

RAIL CRANES.—18-ton Brownhoist, steam, 50ft. jib ; 10-ton Grafton, 34ft. jib, diesel conversion ; 8-ton Wilson, steam, 35ft. jib ; 5-ton Grafton, 35ft. jib, diesel conversion ; 5-ton Smith, 50ft. jib (2).

LOCOS.—Fowler diesel, 150 h.p. (2) ; Barclay & Ruston 80/88 h.p. diesel ; Bagnall 14in. by 22in. (two oil-fired, one coal), Peckett, steam, 7in. by 12in., 1941 ; also 3 miles track, 24in. gauge, Bogies, Turnouts, &c.

STEEL PIPING.—50,000ft., 2in. Galvanised, new ; 60,000ft., 3in., black, new ; 5000ft., 8in. seamless ; 1000ft., 12in. seamless ; 500ft., 14in. seamless ; 400ft., 18in. riveted ; 280ft., 21in. o.d. welded flanged ; 3800ft., 21in. seamless flanged ; 500ft., 24in. riveted ; 1450ft., 27in. o.d. welded flanged ; 216ft., 48in. riveted ; 216ft., 60in. riveted.

CAST IRON PIPES.—Large stocks all sizes up to 24in. flanged and s.s. Immediate delivery.

VALVES.—Exceptional Surplus Ministry Lot. New Stainless Acid Cocks and Valves, over 5000, immediate delivery, below makers' prices. Large stock all sizes, Parallel Slide Sluices, Gunmetal, Reducing and Check Valves. List on request.

STORAGE TANKS.—300 cylindrical and rectangular up to 12,000 gallons, for oil and petrol, also sectional steel and cast iron up to 50,000 gallons.

MACHINE TOOLS.—Heenan & Froude Dynamometers, 1500 h.p. maximum, 18in. Dial Indicator (three) ; Scriven Plate Bending Rolls, 14ft. by ¾in.; Berry Bending Rolls, 7ft. by ¼in.; Tangye 200-ton Hydraulic Vertical Straightening Press, 15ft. by 3ft. table ; Herbert Miller, 61in. by 15in. table ; Pels Punch and Shears, ¾in. capacity ; nine new 2 cwt. and 1 cwt. Pneumatic Hammers ; Bonn Hydraulic Tube Bender up to 20ft. by 4in. bore ; 40kVA. Sciaky Spot Welding Machine ; Berry Guillotine, capacity 4ft. by 1in. ; Fielding Hydraulic Tube Bending Machine, 24in. stroke up to 8in. capacity ; Sedgwick 6ft. by ¾in. Folding Machine ; Rushworth Guillotines, 6ft. by ¼in., and 4ft. by ¼in. ; Bliss 70-ton power press.

SLING ENGINEERING WORKS
COLEFORD, GLOS.
'Phone : Coleford 2271/2. E106 G

FOUR BROOM & WADE TYPE D.22 COMPRESSORS, complete with 27 h.p. motors, starters and aftercoolers. Four Lacy-Hulbert Type V.4AA Vacuum Pumps complete with 13 h.p. motors. All in good condition. Appointments to view.—BOX No. E9640, "The Engineer." G

FOR SALE

HYDRAULIC PRESSES
OF ALL TYPES

10,000-ton Hydraulic Free Forging Press, bed 13ft. by 8ft., stroke 8ft. 3in., with accumulator and pumps, approx. weight 1300 tons.

4000-ton Multi-Daylight Hot Plate Press, four rams, platens 8ft. 6in. by 4ft. 6in., with self-contained pumping unit.

3000-ton Heavy Forming or Drawing Press, table 10ft. 6in. by 6ft.

2000-ton Forging Press, bed 8ft. by 8ft., 11ft. daylight.

1250-ton Vertical Extrusion Press, with self-contained pumping unit.

500-ton Flanging Press, vice rams, table 10ft. diameter.

REED BROTHERS (ENGINEERING), LTD.,
Replant Works,
Woolwich Industrial Estate,
London, S.E.18.
Tel.: Woolwich 7611/6. E9376 G

600

FOR SALE

UNUSED ALUMINIUM SWARF GRINDING DRYING AND CASTING PLANT by Edgar Allen, comprising Stag Pulveriser Rotary Drier, Elevators, Hopper, Mobile Ingot Casting Machine, &c.

Reply :

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		Main Location	*Auctioneers*
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May 10	**Machine tools and miscellaneous stores,** including :—	M.O.A. Storage Depot, **Byley, Nr. Middlewich, Cheshire.** (Sale at Cheetham Town Hall, Manchester, 8.)	**J. H. NORRIS & SON** (Dept. L), 9, Albert Square, Manchester, 2. (Tel.: Blackfriars 8373.)

Centre and turret lathes; pedestal and bench drills; surface and bench grinders; power hammer; M.T. spares; tilt sheets; tyres and tubes; electric motors; fluorescent and other lighting fittings; Lister 22kW and other generators; radio and electrical equipment; fan units; portable cranes; lift trucks and stillages; metal pallets; laboratory glassware and equipment; furniture; steel storage units; canteen equipment; Caterpillar type R.D.6. Bulldozer; greatcoats; overalls; khaki shirts; vests; etc.

May 17/20	**Vehicles, motor cycles, earth moving and lifting equipment.**	M.O.A. Storage Depot, **Ruddington, Notts.**	**WALKER, WALTON & HANSON** (Dept. L), Byard Lane, Bridlesmith Gate, Nottingham. (Tel.: 54272.)
May 20	**Clothing and miscellaneous stores.**	Command Ordnance Depot, **Coypool, Marsh Mills, Plymouth.** (Sale at Kinterbury House.)	**WOOLLAND, SON & MANICO** (Dept. L), Kinterbury House, St. Andrew's Cross, Plymouth. (Tel.: 69292.)
May 24	**Miscellaneous stores.**	Command Ordnance Sub-Depot, **Devizes.** (Sale at Corn Exchange, Devizes.)	**FARRANT, WIGHTMAN & PINNIGAR** (Dept. L), 2, Newport Street, Swindon, Wilts. (Tel.: 5151/2.)
June 10	**Machine tools and miscellaneous stores.**	Technical Stores Depot, **Old Dalby, Leics.** (Sale at Melton Mowbray.)	**SHOULER & SON** (Dept. L), 1, Norman Street, Melton Mowbray, Leics. (Tel.: 3081.)
June 16	**Miscellaneous stores and vehicles.**	M.O.A. Storage Depot, **Bowhouse, Hurlford, Nr. Kilmarnock, Ayrshire.**	**DIXON & WALLACE, LTD.** (Dept. L), Bank Buildings, Graham Street, Glasgow, E.1. (Tel.: Bridgeton 2447/9.)
June 2	**Miscellaneous stores.**	Northern Command Ordnance Sub-Depot, **Barlow, Nr. Selby, Yorks.**	**BARTLE & SON** (Dept. L), 50–52, Menion Street, Leeds, 2. (Tel.: 2 0898.)

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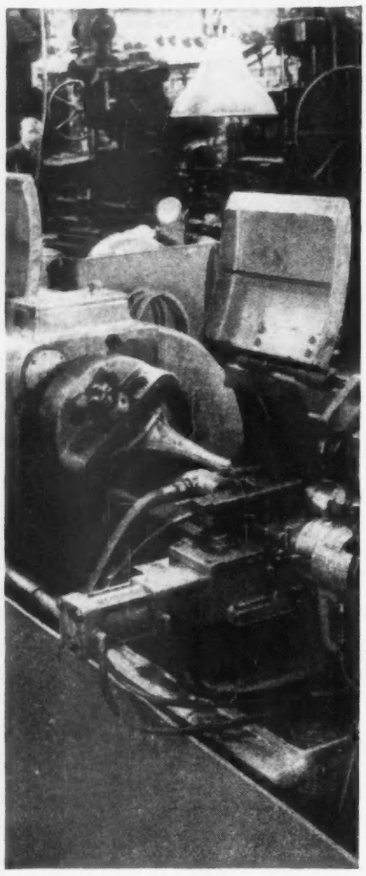

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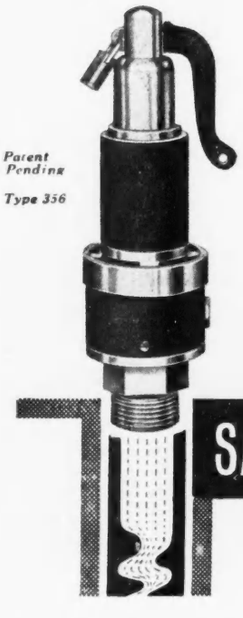

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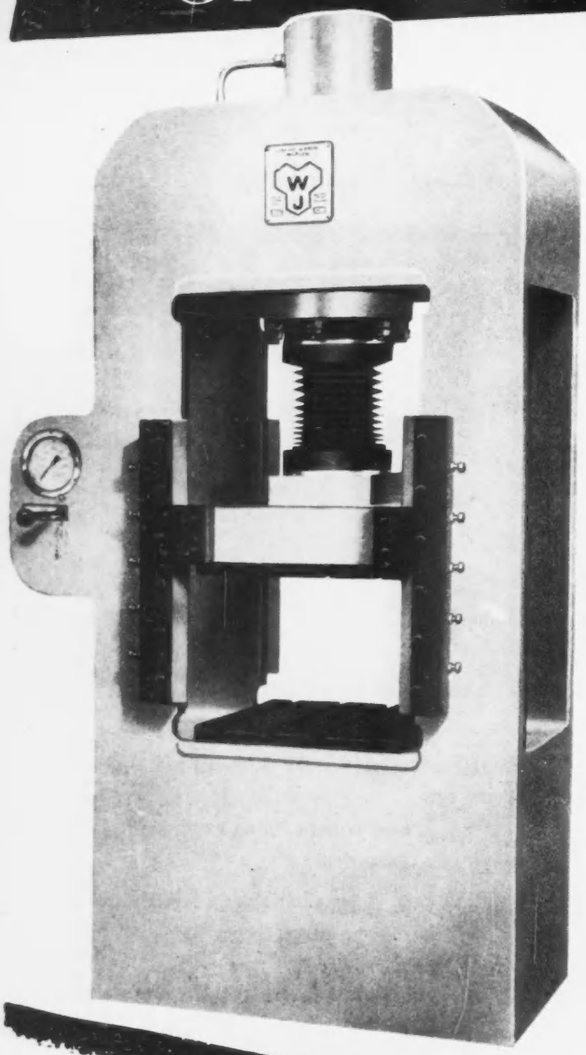

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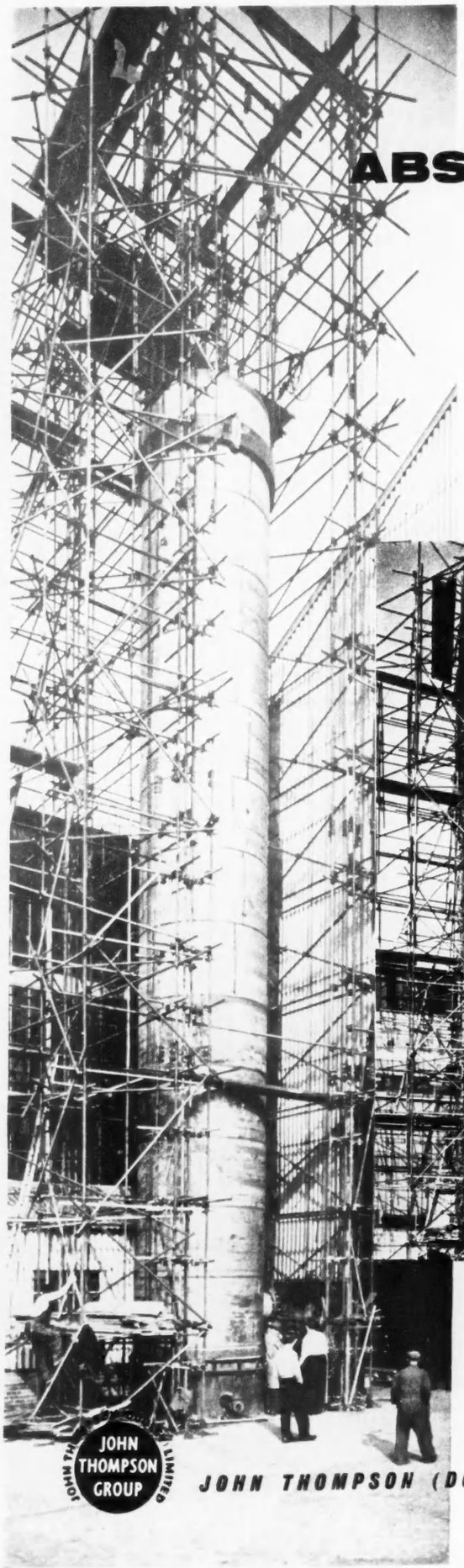

One of Six ABSORPTION COLUMNS for ICI

The illustrations show the arrangements for the hydraulic testing in the upright position of one of six absorption columns made by John Thompson (Dudley) Ltd. for the I.C.I. weak acid plant at Ardeer.

The columns are of welded construction, made throughout in stainless steel. All are fitted with sprays and guides, some with conical intermediate baffles. Longitudinal welds are to Class I standards. The heaviest column weighs 13 tons; length of each column 62ft. 4in.

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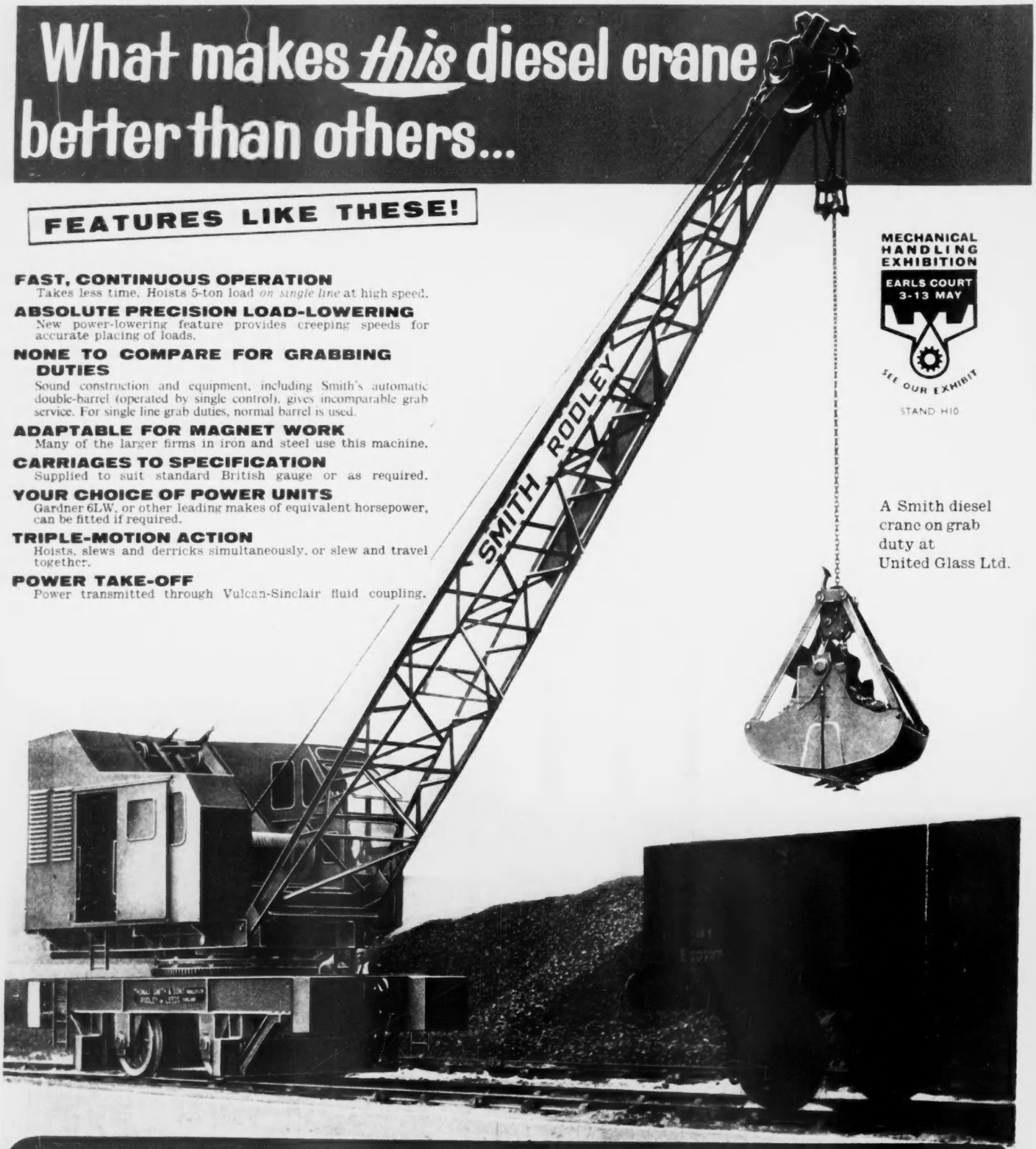

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